crescendo:
2×140watt mosfet power amp

the power supply:
0 to 30 volts, 3 amps

triopodus electrus diclopus:
a phototropic whatsit

ioniser:
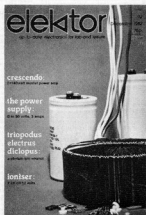7 kV off 12 volts

contents

contents

elektor

crescendo:

the power
supply

triopodus
electrus
diclopus:

ioniser:

*The next issue may be more
of a surprise than just being a
new year. As far as projects
are concerned the January
issue will continue with the
XL system by introducing the
accessories for the power
amplifier, a video/audio
modulator, and . . . it will be
a great start to 1983!*

services to readers

EPS print service

Many Elektor circuits are accompanied by printed circuit designs. Some of these designs, but not all, are also available as ready-etched and pre-drilled boards, which can be ordered from any of our offices. A complete list of the available boards is published under the heading 'EPS print service' in every issue. Delivery time is approximately three weeks.

It should be noted however that only boards which have at some time been published in the EPS list are available; the fact that a design for a board is published in a particular article does not necessarily imply that it can be supplied by Elektor.

Technical queries

Please enclose a stamped, self-addressed envelope; readers outside UK please enclose an IRC instead of stamps.

Letters should be addressed to the department concerned — TQE (Technical Queries). Although we feel that this is an essential service to readers, we regret that certain restrictions are necessary:

1. Questions that are not related to articles published in Elektor cannot be answered.

2. Questions concerning the connection of Elektor designs to other units (e.g. existing equipment) cannot normally be answered. An answer can only be based on a comparison of our design specifications with those of the other equipment.

3. Questions about suppliers for components are usually answered on the basis of advertisements, and readers can usually check these themselves.

4. As far as possible, answers will be on standard reply forms.

We trust that our readers will understand the reasons for these restrictions. On the one hand we feel that all technical queries should be answered as quickly and completely as possible; on the other hand this must not lead to overloading of our technical staff as this could lead to blown fuses and reduced quality in future issues.

THE PROFESSIONAL APPROACH
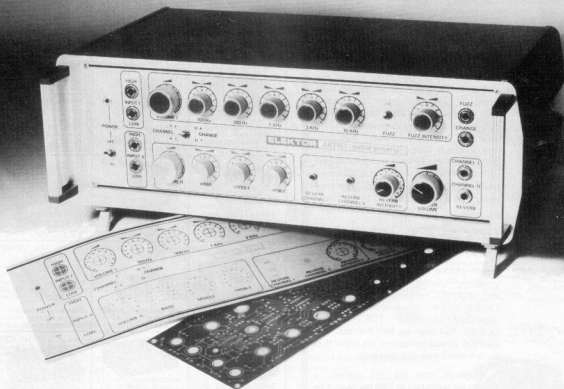
Elektor, the first in the field to provide a printed circuit board....
and now, the first to bring you a fascia panel

selektor

new sense of direction

solid-state gyros . . .

Conventional gyros have to be accurately machined and are very expensive. Moreover, they are delicate mechanisms vulnerable to shock or vibration. Far more robust and cheap to produce is a new device based on a cylinder's flexural mode of vibration and the effect of Coriolis force.

Imagine a fleet of fork-lift trucks moving about a warehouse or factory, following precisely the routes they are instructed to take and automatically correcting any error in direction, but all without drivers. This is but one application foreseen for a novel device with a diameter of only 17 mm and 25 mm long.

The device can be called variously a solid-state gyro or a rate gyro or a rate sensor. It was invented and is being developed by GEC Marconi Electronics at its research laboratories at Great Baddow in eastern England. The scientist concerned who demonstrated the device recently to members of the Royal Society in London is Dr R. M. Langdon, who has used the three different names and has researched the subject for a couple of years.

The word gyro could perhaps be a little misleading because of our preconceptions. We know that it is a wheel or disc or cylinder rotating at a very high speed and often mounted in a complete set

Basic shape of the solid-state gyro.

of gimbals. Simple gyros have been sold as toys, but the complete mathematical behaviour of such a device is far from simple (it involves vector analysis) and need not be considered here.

Gyros have had and still have many successful uses, for example as compasses for navigation, in stabilizers for ships, in monorail vehicles, and so on, apart from military applications. These are the gyros we are familiar with, but the new Marconi device is quite different. For one thing it has no heavy, fast-rotating wheel or cylinder driven by a motor. It has no bearings in which anything moves. Yet it can do what many conventional gyros can do. That is why it is often called a gyro. It measures the rate of rotation of any vehicle in which it is mounted, so it is of the type known as a rate gyro.

Virtually indestructible

The reason for the search for newer devices to do most of the things that mechanical gyros do it that the latter are very expensive: their machining has to be extremely accurate so that there is negligible friction and no imbalance. So the gyros that are used for such tasks as navigation are very expensive — the smallest may cost as much as £ 1000. Furthermore, they are vulnerable to severe shock or vibration. A much cheaper device to do the same job yet be so robust that it is virtually indestructible is obviously a desirable product with a big potential market.

Several scientists and engineers have used their skills to invent such new devices, relying on periodic vibrations instead of mechanical rotation. The earliest was a tuning-fork mounted vertically, its stem being of such dimensions that any torsional vibration would be of the same frequency as that of the tines. When the whole fork was rotated, the torsional vibration set up was measured and was proportional to the rate at which the fork was rotating. It was in effect a rate gyro. Other devices have utilized vibrating wires or rods, but little is known about them. As for the tuning-fork device,

despite intensive work in the USA and at the Royal Aircraft Establishment in Britain, it has not come into production, presumably because of the complexity needed for a satisfactory instrument and the cost of careful machining.

Coriolis force

At this stage of the argument it is necessary to introduce the notion of the Coriolis force, named after the French engineer and mathematician who postulated it in work published in 1835. He was concerned with the limitations of the Newtonian equations of motion in a rotating frame of reference. So he added another force in such a system, and when he did so the Newtonian equations could be used. (Physicists and mathematicians spent about a century searching for an 'absolute' frame of reference only to find that they were chasing a will-o'-the-wisp, so a radical change of approach was needed, culminating in Einstein's Relativity Theory.)

Early use of the Coriolis-force idea was in calculations of ballistic trajectories, because the Earth is a rotating body. Oceanologists and meteorologists have invoked the Coriolis force to account for ocean and air motions. More recently scientists have used it in connection with rotating systems such as gyros.

It is the Coriolis force that comes into the explanation of how the Marconi device behaves. Basically, the device is a cylinder of metal, so asymmetric difficulty is avoided. It looks somewhat like a wine-glass, and everyone knows that is such as glass is struck near the rim it emits a ringing sound, just as a bell does. The fundamental frequency of the tone it gives off depends on the dimensions and the elastic modulus of the material. If we could observe it from above, the vibrations would be seen as shown, grossly exaggerated, in the diagrams a, b and c. So the first problem is how to produce and maintain the vibration. This is done by means of piezoelectric crystals. Such a crystal will produce a vibratory motion in response to an applied oscillatory

Vibrating cylinder

Thick base

Mount
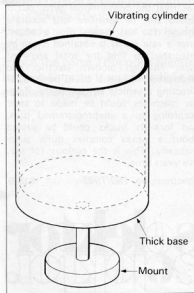
Flexural vibration of the cylindrical cross-section, shown undistorted (a) and subjected to forces as indicated in (b) and (c).

(a)   (b)   (c)
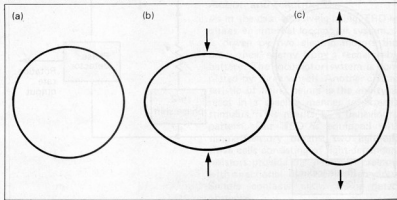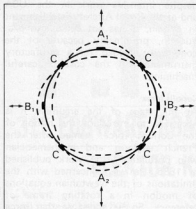
Superimposing the distortions caused by flexural vibration, produced by applying an oscillatory voltage to transducers at A_1 and A_2, shows that nodes appear at points marked C. Other transducers at B_1 and B_2 serve as sensors to pick up the movement and convert it back into an alternating electrical signal.

electrical signal; conversely, it produces an oscillating current when made to vibrate physically. Moreover, it can be made very thin and small.

In the combined diagram, the three parts of the previous diagram are superimposed, with piezoelectric crystals mounted as shown at A_1 and A_2 and at right angles at B_1 and B_2. The oscillatory circuit is connected to A_1 and A_2 while B_1 and B_2 are used as sensors to pick up the mechanical movement and convert it into electrical alternations. There are also piezoelectric crystals quipositioned between the As and Bs, and it can be seen that when the cylinder is stationary there is a node at each position marked C. That is to say, there is no movement of the cylinder wall at those places, so there is no electrical output from the C crystals. The symmetrical way the crystals are arranged helps maintain the overall symmetry.

In practice there are various electronic circuits connected to several of the crystals, but we need not go into the detail. Some of the circuits maintain the frequency, others effect corrections, and so on.

Distorting force

Now let us suppose that the cylinder rotates about its central longitudinal axis. Immediately, the Coriolis force comes into play. The effect is to add a tangential force to the force along the diameter of the cylinder, that is, the force direction for the vibration. As a result there is distortion of the movement of the points marked C are no longer nodes; instead, there is some movement outwards and inwards. This is sensed by the transducers at C and can be measured electronically. The amplitude of the electrical signal so produced is directly proportional to the rate of rotation. When the signal is rectified, and thereby changed into a direct-current signal, its strength can be shown on a meter which, suitably calibrated, gives a direct reading of the rotation rate.

This sounds simple enough, but a great deal has been left out of the explanation in order to keep it readily understandable. For example, it is not easy to find the exact point where there is a node, so two transducers may be needed, with subsequent electronic treatment. To overcome the difficulty, a better method of measurement has been used. A signal that is 90 degrees out of phase with the input signal at A_1 is added to the output from C. Fairly simple mathematics then shows that the signal to be used is shifted in phase and that the shift is directly proportional to the rate of rotation. With this technique there is greater sensitivity.

Such a device must be inside a cylindrical cover for protection. The first, made for investigation, had an overall length of 85 mm and a diameter of 50 mm. It was made of brass and had
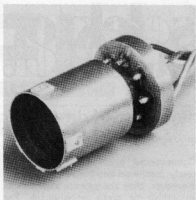
Miniature version of the rate sensor, measuring 25 mm x 17 mm.

a fundamental vibration frequency of about 3 kHz. Many experiments were done with it to discover the next practical steps necessary in the research and development. For example, would temperature affect the performance? What adhesive would be best both for adhesion and electrical conductivity to the metal? How much would the distance between active cylinder and the surrounding cover affect the accuracy? Many such questions affecting the accuracy, stability, sensitivity, ease of manufacture, and so on were raised for continued investigation. And what about miniaturization? A much smaller one was made and it worked satisfactorily. It was that version which was shown recently in London.

So the correctness of the basic assumptions has been proved, and the company has been careful about worldwide patents. However, there is still a lot to be done and it will be a few years before there will be a product suitable for marketing.

The device is indestructible and unaffected by shock or vibration, and it would be inexpensive to produce. For the most delicate applications it would not rival the conventional gyro, but it would still be sensitive and accurate enough for many uses. For example, once a rate signal is obtained it can be integrated to find the total angle of turn. Through modern electrics and electronics, the signal could be used for directing a vehicle automatically. Tractor machines could be made to steer according to a preprogrammed plan, and fork-lift trucks could be guided about a works complex quite automatically. This is the outlook for say, five years time.

Spectrum, no. 180/1982   (833 S)

Sensor circuit arrangement for variable-phase output.
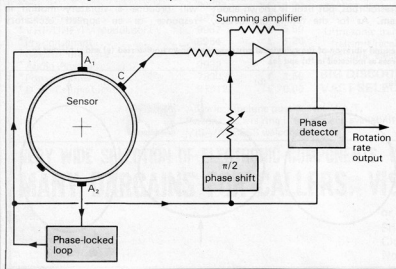
triopede

Tripodus Electrus Diclopus (TED) . . .

J. Cornelissen
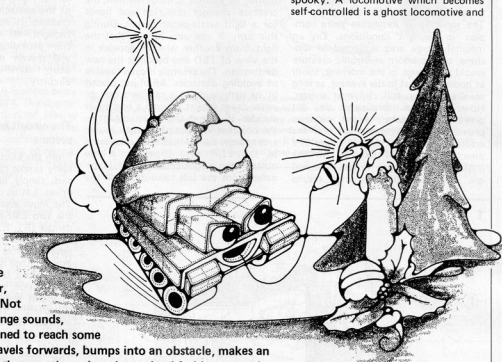
People will be
astonished to see this
three-wheeled creature
moving along the floor,
buzzing and chirping. Not
only does it make strange sounds,
but it appears determined to reach some
destination. First it travels forwards, bumps into an obstacle, makes an
elegant reverse U-turn then continues in a determined fashion towards
some invisible destination. After careful observation of its behaviour,
the only conclusion that can be drawn is that the creature is a light-
addict!
Hence the name Tripodus Electrus Diclopus, or TED for short.
In normal terms it means: a light seeking, three wheeled, electro-
mechanical hybrid.

The built-in electronic instinct is pro-
grammed to seek the brightest point in
the room. A deviation routine in the
logic circuit ensures that it cleverly
avoids the many obstacles on its path
towards the light.

For specialists it is clearly a simple
cybernetic model. But to other, un-
biased observers it is a spectacular
electronic monster. For domestic pets
it is a strange encounter of the third
kind. For electronic hobbyists it is a
lot of fun.

When a technical creation becomes
self-controlled it usually appears mon-
strous to us humans. Inanimate objects
are supposed to be 'dead' and indepen-
dent action is associated with living
beings. Exceptions to this rule are
spooky. A locomotive which becomes
self-controlled is a ghost locomotive and
when inanimate objects move without
being instructed to do so it is eery. This
is what we are dealing with here. It is
small, a bit weird but a lot of fun.

Action and reaction

As in the case of a living being, TED re-
quires an internal locomotor system. It
is driven by two electric motors that
draw their energy from a rechargeable
battery. The locomotor system is com-
pleted by three wheels. Another charac-
teristic of living beings is the ability to
react in a specific manner to external
stimulus. This results in a behavioural
pattern. Our TED is equipped with
simple sensory organs: two light-sen-
sitive cells consisting of light-dependent
resistors provide the electronic creature
with directional, light-seeking behaviour.
Simple contacts allow it to detect
obstacles.

The two eyes (hence diclopus) are fitted at the front at an adequate distance from each other; they contain LDRs. If the light impinges laterally, then one of the two LDRs is subjected to less light than the other. The result is that the motor's electronic control circuitry executes a change of course which lasts until the light impinges from the front and both LDRs are subjected to the same amount of light.

If there is only one light source in a room with dark walls, our monster will always travel towards this light source. The direction it faced when it was placed on the floor is immaterial (figure 1). There is, however, one exception: when travelling away from the light source, no direct light impinges on the LDRs. Both are dark and TED will travel aimlessly into the darkness.

The situation is somewhat more complex in daylight conditions. On an infinitely large area subjected to sunshine, our stubborn electronic creature would travel east in the morning, south at noon and west in the evening, as long as the battery still delivered energy. However, these conditions do not prevail in a room; several windows provide several light sources and the creature must select one of them. The direction of travel depends on the initial direction when it was switched on. There are often strange results

which cannot be foreseen in the development stage: when faced with a 'difficult decision' the entire system of the creature can start oscillating; this is made noticeable by the creature swinging to and fro on the spot as though it cannot make up its mind. This phenomenon is occasionally encountered in more intelligent beings! The problem was largely solved, however, by an appropriate modification to the circuitry.

Since most windows do not extend down to the floor, the cybernetic creature often changes direction when approaching a window: when it enters the shade area it may suddenly detect a light object that was previously undetected on account of the bright light from the window. Instead of continuing its journey towards the wall, the creature changes direction and heads for a light waste-paper basket. During this turn, it can also happen that the light from another window appears in the view of TED and becomes the new destination. The creature is even capable of avoiding obstacles. An object placed in its path, such as a carboard box or waste-paper basket or even a human, is avoided if — and this is important — the object is in front of the light source and appears darker than the background to the LDR eyes (figure 2). If the obstacle has a light colour and is illuminated from the side towards which the

creature is travelling, it is immediately attacked. Even the light-coloured trousers of Elektor staff members are not spared.

On the other hand, the legs of chairs and tables are not detected. The creature can 'see' about as much as a human who tries to walk towards a light window with his eyes closed. Two sensor contacts are interconnected by means of a bracket which forms a kind of 'front bumper'; this informs the creature when it has bumped into an undetected obstacle. When the bumper touches an object the creature's 'vision' is briefly disabled and it executes an 'instinctive action'. It reverses for a short distance (to obtain sufficient space for a change in direction) then makes a turn to the left or right, depending on the location of the obstacle. Luckily, our electronic creature is not capable of intelligent thought. Its creators wisely refrained from providing it with a computer brain and merely made use of simple and easily constructed, hard-wired logic circuitry.

The circuit or simple nervous system

From the electronic viewpoint TED is a fairly simple creature: it has simple sensors, simple logic circuitry and simple drives. Let us consider the sensors first. The most important sensory organs are the two LDRs which form a potential divider (R1, R2). When subjected to the same amount of light the two LDRs have the same resistance; half the operating voltage is then applied to the midpoint. Two triggers without hysteresis ensure that any deviation from this midpoint results in a binary signal for 'right/left'. The two LEDs D3/D4 indicate the initial state and are indispensable for alignment, as described later.

The following memory stage IC2 prevents direct feedback from the drive (direction control) to the direction indicators (LDRs). If the LDRs were to control the drive motors directly, hunting or oscillating could easily occur. In order to avoid such nervous overreactions the creature was given a 'tranquiliser' in the form of IC2. This ensures that the results of its sensory perception are passed on with a slight delay, whenever clock generator A3 emits a pulse. TED blinks, so to speak, at the rhythm of the clock generator. LED D5 also flashes with each clock pulse, to make the blinking noticeable.

Direction control and drive are interrelated: this is an integrated function of the type used by track-laying vehicles. Each of the two drive wheels has its own motor and each motor has its own control system. When the directions of rotation are in opposition the TED turns on its own axis. When the directions of rotation are the same it
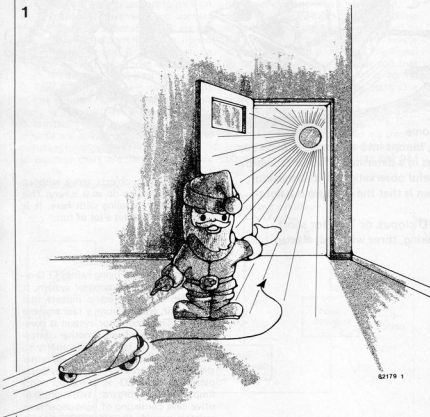
Figure 1. If there is only one light source in a room with dark walls, TED will always travel towards this light source. The direction it faced when placed on the floor is immaterial.

travels forwards or backwards, depending on the polarity of the motor supply. A bridge circuit of four transistors for each motor caters for polarity inversion. Driving of the bridge output stages is simply performed by inverting CMOS buffers (N17 . . . N20). Since the motors are controlled digitally and not proportionally, the power loss is very low. As much of the battery energy as possible is made available for the drive system.

So that TED will not 'give up the ghost' in front of every obstacle, the circuitry contains a deviation logic circuit. A front bumper is mounted on two sensors that require only slight pressure for actuation. When an obstacle is bumped into, these sensors deliver a logic '0' to the inputs of the flip-flop consisting of the two NAND gates N1 and N2, and to the inputs of gate N3. N3 represents an OR-function for the sensor signals: as soon as a sensor is actuated by a collision, N3 delivers a pulse to the two monostables N13/N14 and N15/N16. The duration of the toggled state of N15/N16 is about twice as long as that of N13/N14. The shorter time governs the duration of reverse travel and the longer time governs the total duration of the avoiding action. The whole operation consists of reverse travel of about one length of the creature, followed by a 90° turn.

In the event of a reaction to light (no collision) both pin 9 of N9 and pin 5 of N10 are at logic '1'. The information from the latch is allowed to pass. At the following OR-gates N7 and N8, pin 13 (N7) and pin 1 (N8) are at logic '0'. This means that only the 'visual' information is allowed to pass here also (logic signals at the outputs of N9 and N10). When an obstacle is bumped into, both monostable outputs (pin 4 of N14 and pin 10 of N16) are first at logic '1'. This causes pin 3 of N4 to go to logic '0'; N8 and N10 are inhibited. The outputs of N7 and N8 are now at logic '1' until the monostable consisting of N13 and N14 reverts to logic '0' at its output: TED travels backwards!

Where do the two 'ones' come from? The outputs of N5 and N6 are at logic '1' because the interconnected inputs (pins 9 and 5) receive a logic '1' from the monostable. N11 and N12 allow these logic 'ones' to pass, because their interconnected inputs receive a logic '1' from the second monostable.

If monostable 1 toggles back to zero, the state of the flip-flop must be transferred to the motors: it determines whether a turn to the left or right is made. If the output of the first monostable goes to zero, N5 and N6 deliver the flip-flop information via N11, N12, N7 and N8 to the motors. N11 and N12 are only inhibited when the second ('longer') monostable reverts to zero somewhat later. N9 and N10 are enabled again, thus restoring the original state.

Figure 2. Since most windows do not extend down to the floor, the cybernetic creature often changes direction when travelling towards a window: when it penetrates the shade area, light objects are suddenly detected which were not noticed in the bright light of the window. When placed in its path, an object such as a cardboard box, waste-paper basket or even a human is avoided if — and this is important — it is between the light source and the creature and is therefore considered as background when viewed by the LDR 'eyes'.

Figure 3. The circuit of the cybernetic creature, our TED evaluates the light impinging on R1 and R2; T1 . . . T8 provide the motor control circuitry; S1 and S2 evaluate 'contact with the enemy' and the sound generator with loudspeaker gives the creature its speech.

Construction

The electronic circuitry should present no problem and can simply be assembled on the printed circuit board shown in figure 4. Care must be taken to insert all ten wire links and to ensure that the cooling surfaces of all nine power transistors are facing R9/R8. When all components have been fitted to the board and inspected, we can turn to the mechanical construction of TED.

Figure 5 shows the solution as tested in the Elektor laboratory. Of course, many versions are possible. A base supports the printed circuit board and the rechargeable battery. The battery voltage is 6 V. Although the CMOS ICs and LEDs consume relatively little power, the motors draw approximately 250 to 300 mA under load (rolling resistance, friction of the gearbox and drive belt). Normal dry batteries would be inadequate; for this reason a rechargeable battery with a minimum capacity of 0.6 Ah was chosen. It powers both the motors and the electronic control circuitry. Any interference generated by the motors has no effect on the control circuitry. The two LDRs which form the 'eyes' are mounted externally on the left and right. The loudspeaker and battery switch S3 must also be connected and mounted somewhere on the base.

Switches S1 and S2 are assigned particular locations as are the LDRs. They are mounted on a bracket which serves as the 'bumper'. If the creature bumps into an obstacle, one of the two sensors closes and activates the electronic circuitry. LEDs D3, D4 and D5 are first mounted on the printed circuit board. Later, when TED has assumed its final form, they can be mounted elsewhere to improve the appearance. The base is propelled by two motors. We used two 6 V/350 mA motors. The worm drive was fitted with a gear and pulley that supports the drive belt at the motor end; the belt is a rubber band of the type used for sealing preserving jars. Situated at the wheel end is a gearbox which steps down the rotary motion transferred by the belt. Mounted at the input of the gearbox is a pulley of the same size as that at the motor. Thus the motor speed is transferred to the gearbox at a ratio of 1:1. The drive
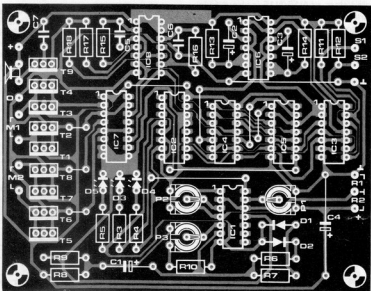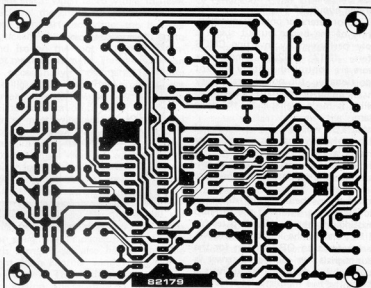
Figure 4. Track pattern and component layout of the printed circuit board for the Triopede. Ensure that all ten wire links are inserted and that the cooling surfaces of all nine power transistors are facing R9/R8.

wheel, which rotates approximately 14...16-times more slowly than the belt pulley, is positioned at the output of the gearbox.

With this design the creature reaches a speed of approximately 10 cm per second, which corresponds to 0.36 km an hour. The LDRs are darkened at the rear using an indelible marking pen or black adhesive tape. No shielding against lateral light is required.

Alignment

P1, P2:

These are used to establish the 'blind zone' in the visual range of TED. A change of direction of a light source within this blind zone must not cause any change in course. If the range of tolerance becomes too small or even zero, 'motor hunting' can occur, as already mentioned. If it is too great, obstacles can no longer be detected in time.

A room is chosen with a light source in the form of a single spot if possible (small window or light bulb). Place TED on the floor at a distance of a few metres from the light source and facing it with both 'eyes'. Then rotate it about 10 degrees to the left. More light now impinges on LDR1: the voltage at point A becomes greater than

5

Figure 5. Here is the construction tested in the Elektor laboratory. A base supports the printed circuit board and the rechargeable battery. This base is propelled by two motors whose speed is reduced by gearboxes. The creature reaches a speed of 0.36 km/h.

82179 5

Parts list

Resistors:
R1,R2 = LDR
R3,R4,R5 = 470 Ω
R6,R15 = 22 k
R7 = 1 k
R8,R9,R17,R18 = 10 k
R10 = 2k2
R11,R12 = 47 k
R13 = 470 k
R14 = 1 M
R 16 = 33 k
P1,P2,P3 = 10 k trimmer

Capacitors:
C1,C2,C3 = 4µ7/16 V
C4 = 470 µ/16 V
C5,C6 = 47 n
C7 = 100 n

Semiconductors:
D1,D2 = 1N4148
D3,D4,D5 = LED
T1,T3,T5,T7 = BD 239C
T2,T4,T6,T8,T9 = BD 240C
IC1 = LM 324
IC2 = 4042
IC3 = 4011
IC4 = 4071
IC5 = 4081
IC6 = 4001
IC7 = 4049
IC8 = 4093

Miscellaneous:
LS = loudspeaker 8 Ω/0.2 W
S1,S2 = sensors (pushbuttons)
S3 = on/off switch
6 V rechargeable battery, 0.6 Ah min.

U/2. Adjust P1 so that LED 1 just begins to light up. Now rotate TED the same number of degrees to the right. Adjust P2 so that LED 2 just begins to light up.

During forward travel (with the light source dead ahead), neither of the two LEDs must light up. LED 1 and LED 2 must never light up simultaneously. This can, however, result from an incorrect adjustment of P1 and P2. Fine adjustment of the clock frequency can only be made while the creature is travelling. Its speed is very important. The clock frequency can only be adjusted to suit the mechanical construction of the propulsion system after a few trial runs. It is also interesting to observe the change in behaviour of the creature at different clock frequencies (approximately 2-10 Hz).

When it is switched on TED acts as though it had just bumped into an obstacle. Wait until the reverse travel and subsequent rotation have ended. For a functional test it is advisable to disconnect the link between the motors and the drive wheels.

Connecting the motors

The motors must be connected with the correct polarity so that TED will not unintentionally travel backwards or in a circle. The procedure is as follows:
1. Illuminate the LDRs in such a way that D3 and D4 do not light up. The

two motors should now rotate for forward travel if they were properly connected.
2. Rotate TED so that the light source is at the front right (as viewed by TED). The right drive wheel should now rotate backwards and the left wheel forwards.
3. Rotate TED so that the light source is at the front left. The motors should now change their direction of rotation. The left wheel should run backwards and the right wheel forwards.
4. If, after bumping against an obstacle and reverse travel, the creature turns towards the obstacle instead of away from it, S1 and S2 should be interchanged.

Finally . . .

. . . all that is left is the final appearance of TED and this is a matter for individual appreciation. However, we would advise against a terrifying exterior; the 'cybernetic look' is probably quite sufficient. Have fun.

◀

If any circuit is to be accurately and safely tested a good power supply must be used. It is not sufficient for it to be just a stabilised supply, it must also include some form of protection against faults arising in the circuit under test. This usually takes the form of current limiting and output short circuit protection.

In order for it to fulfil its function correctly, a power supply should have the following facilities.

- The ability to deliver fairly high current levels at voltages of 24 V or more.
- It must be completely stable at all output conditions.
- The output must have some form of short circuit protection.
- Current limiting control up to the maximum current output.
- An output voltage control that is fully variable from 0 to maximum.
- Accurate indication of both current and voltage output levels.
- Sense inputs to allow compensation for voltage drops when long supply cables are necessary.

Although the last two points are not strictly necessary, their inclusion makes the power supply more versatile and easier to use.

The precision power supply here follows the standards set by commercial equipment and includes all of the above features. It has a variable output voltage range of 0 to 35 V and continuously variable current limiting up to 3 amps. The performance is on a par with fairly expensive commercial power supplies but approaches the stabilisation problems with a rather novel circuit design.

The principles

The vast majority of power supplies use either 'series' or 'pass' regulation. This means that the stabilising power transistors are connected (effectively) in series or in parallel to the load. In common with most designs the circuit here utilises series pass regulation. The originality in the circuit design is the method used for stabilisation.

The block diagram in figure 1a illustrates the principle of a conventional series regulator. The active element of the cir-

Good control
with high power

precision power supply

Any item of test equipment is useful but only one is absolutely necessary and that is some form of power supply. These normally provide a voltage output of up to 25 or 30 volts at about 1 amp which is fine for most purposes. However, this current level can be rather limiting when testing computers, audio amplifiers and other high power equipment. It is essential too that some form of protection such as current limiting is included in the circuit design. The precision power supply here is capable of providing up to 3 amps at 35 V and incorporates both current limiting and short circuit protection. Meters are included to enable current and voltage output levels to be monitored.
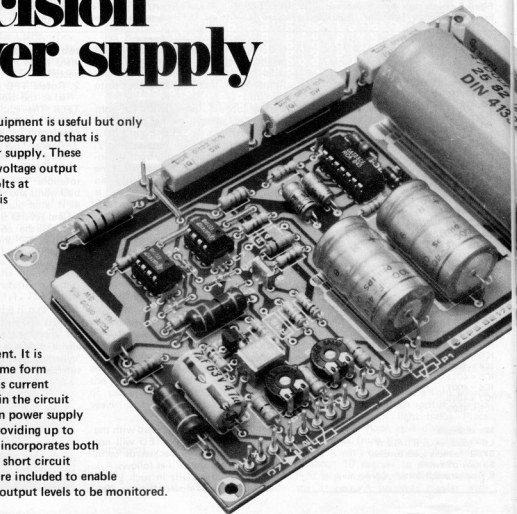
cuit is opamp A and its output is the source of the load current, that is, in series with the load R_L. The non-inverting input of the opamp is held at a reference voltage, U_{ref}. The inverting input of the opamp is at a voltage level that is a proportion of the input voltage — derived by potentiometer P. Under these conditions the output of the opamp will become stable at the point where the voltage difference between the two inputs is zero. That is, the opamp will maintain a condition where the reference voltage and that at the wiper of potentiometer P are equal. It will be obvious that the output voltage will therefore be dependant on the position of P. With the potentiometer in mid position the output will be double the reference voltage. The disadvantages of this system are that the stability factor is dependant on the setting of potentiometer P, the output can never be lower than the reference voltage and the operation of P will not be linear. Two of these points may not be so significant in some cases but an output minimum that is restricted to the reference voltage will be embarrassing to say the least!

The block diagram of figure 1b provides another solution. In this case, the opamp is used as a unity gain amplifier and P becomes a voltage divider connected across the reference voltage. The output of the opamp will now be proportional to the voltage level at the wiper of P. In this configuration the output range will be between 0 and the reference voltage. This sounds better but it is still far from ideal. The opamp will now require a negative voltage supply rail, an added disadvantage.

The reference voltage must be at least as high as the maximum required output, not an ideal situation! Finally, the stability factor is still a question of potentiometer P.

Figure 1c goes a long way towards removing the problems of the reference voltage, as far as the opamp is concerned, with a reference current. The output voltage is now determined by the current passing through P. The advantage is that the circuit is no longer dependant on the reference voltage level.

We now arrive at figure 1d which, in principle, is very similar to 1c. The reference current in this case is derived from the output voltage via a series resistor R. The idea is not entirely new but the method used here is a little unorthodox.

As previously mentioned, a current source is achieved by placing a resistor in series with a reference voltage derived from the output. However, for this to happen in practice, the value of potentiometer P has to be much lower than R. The opamp still tries to balance out the difference between the voltage levels at its inputs but now the output voltage will be equal to the level on its non-inverting input.

The series resistor is effectively placed between the two inputs of the opamp. However, due to the high impedance of the inputs, theoretically at least, no current can enter the opamp. In effect then, the current derived from the reference source follows the path shown as a dotted line in the block diagram. Since $U_1 = U_2$ (the opamp ensures this) the current level remains constant, totally independant of P and the load. The current level is equal to $\dfrac{U_{ref}}{R}$. The opamp will balance out the voltage across P and, in doing so, the reference current is compensated for any change in load. The result of all this is that the circuit conforms to what we are looking for, a constant reference current (even at 0 V) using a reference voltage source and a resistor.

The precision power supply

The major difference between the block diagram of the precision power supply in figure 2 and that of figure 1d is the fact that two opamps and a series pass power transistor are included. The current source (U_{ref} and R) and the potentiometer P1 are very similar.

The second opamp A2 is responsible for output current limiting. The voltage across the emitter resistor R_S of transistor T is proportional to the output load current. A proportion of the reference voltage is derived by the setting of P2 and this is compared to the voltage across R_S by opamp A2. When the voltage across R_S becomes higher than that set by P2, the opamp reduces the base drive current to T until the difference is reduced to zero. The LED at the output of A2 functions as a current limiter.

The circuit diagram

So much for the theory, now for its practical application. The circuit of the power supply, shown in figure 3, has two independant power supplies (if that makes sense!). The power for the output stage is provided by transformer Tr2 which, of necessity, will be rather a hefty beast. Transformer Tr1 provides power for the reference source and the opamps.

The reference source is derived with the aid of the inevitable 723 (the worlds longest living chip?). The components
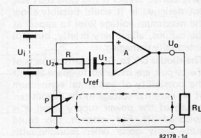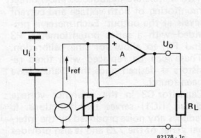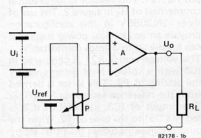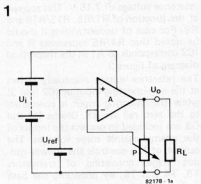
Figure 1. The drawings here, in conjunction with the text, illustrate the advantages of why the use of a constant current reference source is preferable to a reference voltage.

around this IC were chosen to provide a reference voltage of 7.15 V. This appears at the junction of R1/R5, R15/R16 and R9. For ease of understanding it should be noted that R4/R5 represents R and IC2 corresponds to A1 in the theoretical diagram of figure 2.

The reference voltage eventually arrives at the non-inverting input of IC2 (pin 3) while the inverting input is connected to the zero rail via R8. Diodes D2 and D3 are included to protect the inputs of the opamp against surge voltages. The output of IC2 controls the power output stage, consisting of transistors T3, T4 and T5, by providing the base drive current for transistor T2.

A word about transistors T3 . . . T5. These are connected in parallel and their outputs are combined via emitter resistors to provide the power supply output via R21. This resistor is the practical counterpart of R_L in figure 2. The use of three 2N 3055's in this configuration provide an economical power stage that can handle up to 3 amps comfortably.

The voltage across R21 is compared in IC3 with a voltage level determined by the setting of P2. This latter is derived from the reference source via R15/R16. The output of IC3, like that of IC2, is fed (via D5) to the base of T2. When the output current is higher than that set by P2, the output current is reduced by IC3 until the two levels are matched. Transistor T1 and its surrounding components cause the LED D7 to light when current limitation is in effect.

Two meters are included to allow direct monitoring of both voltage and current levels at the output. Each meter is provided with a series potentiometer, P3 and P4, to allow for fine calibration. These can be replaced with fixed resistors if desired once their values have been found.

Capacitor C3 in the reference voltage circuit (IC1) serves two functions. It reduces any noise produced by the internal zener of the 723 and it also provides a 'slow start' for the reference voltage supply. This means that when the power supply is first switched on, the opamps are giving time to 'settle down' before being asked to do any work, a sort of early coffee break! If this slow start was not designed in it could possibly allow the maximum voltage level to appear at the output, albeit very briefly, but still potentially damaging.

The diodes D1 to D8 in various parts of the circuit are included to guard against the possibility of accidental connection of an external voltage to the output terminals of the power supply when it is switched off. For instance, this could quite easily occur when working with a circuit that has a built in battery back-up.

Components R7 and C6 increase the reaction time of the circuit when changing output voltage levels while capacitors C7 and C8 eliminate the possibility of oscillation in the opamps. For stable operation of the circuit a minimum
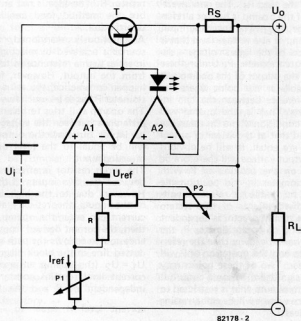
Figure 2. The basic block diagram of the precision power supply. Opamp A1 provides the voltage regulation while A2 takes care of the current limiting.
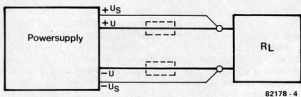
Figure 4. The two sense inputs are used in the manner illustrated here to enable the circuit to compensate for voltage drops caused by the use of long cables.

3

Figure 3. The circuit diagram of the precision power supply. Resistors R4/R5 correspond to R in figure 2, IC2 to A1, IC3 to A2 and R21 to R5. Of the two transformers, Tr1 provides the supply for the reference current source while Tr2 supplies the power for the output stage.

5
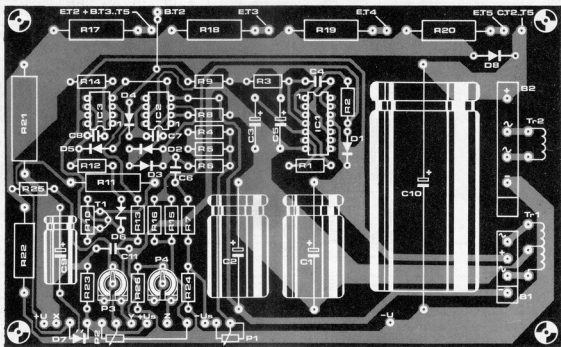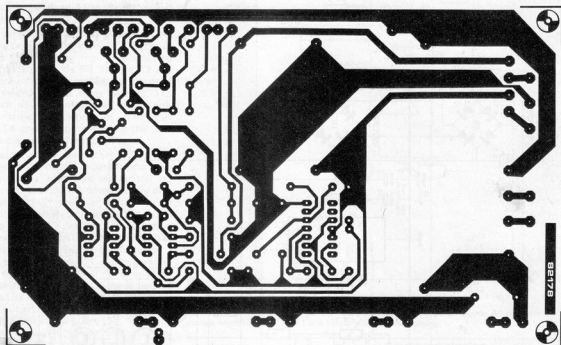
Figure 5. The track pattern and component layout for the printed circuit board used for the precision power supply.

6

Parts list

Resistors:
R1,R3,R6,R8,R12,R13,R14 = 4k7
R2 = 22 Ω
R4,R16 = see text
R5 = 10 k
R7,R10 = 1 k
R9 = 2k2
R11 = 470 Ω/1 W
R15 = 15 k
R17 = 10 Ω/1 W
R18,R19,R20 = 0,22 Ω/3 W
R22 = 4k7/1 W
R23,R24 = 47 Ω
R25 = 5k6
R26 = 270 k
P1 = 50 k potentiometer
P2 = 1 k potentiometer
P3 = 2k5 preset
P4 = 250 k preset

Capacitors:
C1,C2 = 100 μ/25 V
C3 = 100 μ/10 V
C4 = 100 p
C5 = 10 μ/25 V
C6 = 1 n
C7 = 100 p
C8 = 56 p
C9 = 47 μ/63 V
C10 = 4700 μ/63 V
C11 = 820 n
C12 = 100 n

Semiconductors:
B1 = bridge rectifier B40C1000
B2 = bridge rectifier B80C5000/3300
D1,D8 = 1N4001
D2 . . . D5 = 1N4148
D6 = 3V3 400 mW zener
D7 = LED red
T1 = BC 559C
T2 = BD 241
T3,T4,T5 = 2N3055
IC1 = 723
IC2,IC3 = 741

Miscellaneous:
S1 = double pole mains switch
M1,M2 = 100 μA meter
Tr1 = 2 x 12 V/400 mA mains transformer
Tr2 = 33 V/4 A mains transformer
F = 1 A fuse

output load resistance is necessary. This
is taken care of by R22.
It will be noted that there appear to be
more output terminals than the usual
power supply needs. The two extra out-
puts, +U$_S$ and —U$_S$, are in fact inputs.
These so-called 'sense' inputs are used to
allow for voltage drop compensation
when working with long connecting
cables between the power supply and its
load. Figure 4 illustrates how the inputs
are used. Two extra wires are connected
as shown between the load and the
sense inputs. The result of this is that
the supply voltage level is now effectively
measured at the load and not at the out-
put terminals of the power supply. This
enables the circuit to compensate for
any voltage drop resulting from the
resistance in the main supply cables. It
should be noted that if the total resist-
ance of the two main supply cables is
1 Ω, at the current level of 1 A the
voltage drop will be 1 V. In normal use,
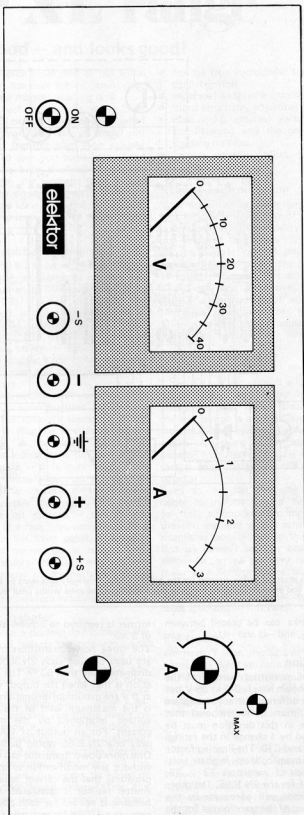
Figure 7. The design of the front panel that is available from Elektor. It is manufactured from
scratch resistant polycarbonate material and is self-adhesive. The illustration is at a reduced
scale, the actual size is 11 cm x 30 cm.

7
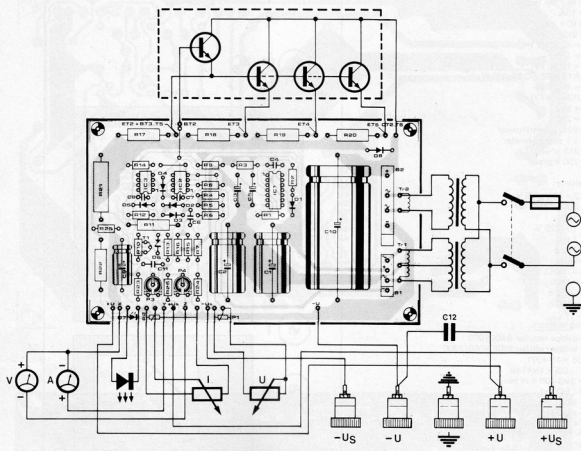
Figure 6. The practical wiring diagram for the power supply. Obviously care must be taken with connections, especially with respect to the transformers and power transistors. Errors in this area will not become visible until the smoke clears!

shorting links can be placed between +U and +U_S, and –U and –U_S.

Construction

The maximum output current of the circuits as shown here is 3 A at 35 V but in principle different current ratings are possible. It must be remembered that any change in this direction must be accompanied by a change in the ratings of both C9 and C10. The limiting factor is the maximum collector/emitter voltage capability of transistors T2 . . . T5. This is 60 V for the 2N 3055. The other deciding factor will of course be the current rating of the transformer for the power output stage. The maximum output of the power supply is a factor $\frac{1}{\sqrt{2}}$ of the current supplied by the transformer which explains why a 4 A trans-

former is required to achieve an output of 3 A.

The three power transistors in parallel are used because each 2N 3055 cannot dissipate more than 50 W. The consideration is that when the output voltage is at 0 V the maximum dissipation required is the maximum level of the rectified voltage multiplied by the maximum current. For an output of 1 A at 35 V only one 2N 3055 would be sufficient. One more power transistor can be added without any modification to the circuit providing that the correct value for the emitter resistor is calculated. A 2°C/W heatsink is needed for each power transistor or a 1°C/W for each pair. Capacitor C12 is mounted directly onto the output terminals as shown in figure 6.

Do not mount the resistors R4 and R16 initially as their value will depend on the maximum output voltage and cur-

rent. For this reason it will not be possible to mount the printed circuit board into the case until test and calibration is completed. Set P1 to maximum, switch on and connect a multimeter to the output of the circuit. By trial and error find the actual value of R4 which gives the maximum required output voltage. This can be done by connecting different resistors in parallel to R5. When the correct value has been found it can be soldered in place on the board. Repeat the exercise with P2 and R16 (in parallel with R15) until the maximum current level is found.

The remaining calibration is that of the meters by adjustment of P3 and P4. It is possible to build the power supply using only one meter. In this case a 2 pole 2 way switch connected to points x, y and z is required to switch between volts and amps.

◄

the Elektor XL range

an audio system that sounds good — and looks good!

Over the years, Elektor has built up a reputation for producing reliable and well-designed circuits for home construction. In the audio field, we have produced preamps that vary from the cheap-and-n . . . not-too-bad to the top quality all-singing-all-dancing variety; power amps from the milliwatt range up to 'quality-power'; noise reduction systems, indicators, distortion measuring gear, a stylus pressure gauge even. Now we've got some more in the pipe-line: the XL range.

In this case, we feel that a general introduction is called for. What is the XL range? What is special about it? In a nutshell, it comprises a series of very high performance audio components that can be built at sensible prices. The quality should come as a pleasant surprise, even to the serious audiophile, and the final appearance needn't be a disgrace to the living room. In other words, it is not intended to be competitive in the low-budget category; nor it is expressly intended to be a competitor in the £1000+ range. High quality, plenty of features if you want them, reliability and a reasonable price: these were the main design goals. Our new front panels add the finishing touch.

How it all started

Way back in '78, one of our many hi-fi enthusiasts drafted an eight-page memo on what we ought to do in this field. It suffered the fate of most memos: interested study, brief discussion, filing cabinet . . . However, the idea kept on nagging in the back of our minds. And when an idea is irritating the grey matter in some two dozen fertile, technically oriented brains, something must happen eventually. Then, early this year, your editor was wondering what large project would be worth tackling in the winter months, as a series of articles. From past experience, a truly consecutive series seemed unwise: no matter how carefully it is planned, the designers always get second thoughts halfway through — and want to redesign some forthcoming part. It then becomes a battle royal to keep the articles appearing at monthly intervals. (For those readers who have wondered why nearly all magazines tend to leave gaps in a series 'for reasons of space': now you know the true reason!)

The two things came together. A series of articles describing a complete audio system! You can publish the various components in any order — and if you miss a month, nobody's any the wiser. Now (second thoughts again!) we decided to play it straight: we'll tell you what we intend to publish, but we don't make any promises as to when! You can

take your pick from one of the stock phrases: in the near future, soon, over the next few months, starting now . . . Over the past six months, we've been having a lot of fun: no-wild-ideas-barred brainstorming! What features would you like? What features seem even vaguely feasible? To give you some idea of the things we've been thinking of, we can run through the various items in the system. No promises, mind! These are 'brainstorm' ideas, and not all of them are economically and/or technically feasible.

Power amplifier: Crescendo

100 W? 250 W? Bandwidth from DC to passing-bat frequencies, or restricted to suit the human ear? Transistors, opamps or MOSFETs? End of discussion: the final circuit is described elsewhere in this issue. As specified in that article, it uses MOSFETs to deliver plenty of undistorted power — enough to coax pleasing sounds at a more than adequate level from even the most inefficient of 8 Ω speakers.

During our think-tank sessions, we dreamed up some features. DC protection for the speakers seemed a 'must' — so we'll describe that next month (promise!). A power-up countdown with visual indication is fun, and avoids nasty thumps — so it is included. Then there's a choice: where do you put the amplifiers? In the rack, on the floor, or in the speaker cabinets? The design caters for all options — but if you mount it in a rack, you need something to put on the front panel. The mains switch, of course; power output indicators, possibly? Hey . . . why not add a thermometer on the heatsinks! When the system is switched off, it will double as room temperature indicator.

Preamp: Prelude

What should a preamp do? It boosts the input signal, selects the one you want, provides tone, volume and balance controls, feeds signals to a tape deck and headphones, and may do a lot more things as well: noise reduction, remote control, level indication . . . Wow! A design that includes everything might be rather expensive, and one that does not include everything might disillusion some audiophile. So what do you do? Make it 'modular'! That way, all the various bits and pieces can be added or omitted according to personal taste. The design that we're finalising at present includes:
- both dynamic and moving-coil preamps that can be tailored to suit virtually any high-quality cartridge
- tone controls that include all mod cons

- for the true audiophile: tone control cancel option
- separate headphone amplifier
- input sensitivity adjustment
- dual input channel switching: one for listening and the other for recording on tape
- remote control option, as outlined below

Remote control: Baton

Your editor would have liked a system that included motor-drive of the control potentiometers. No quality loss, and just think of the 'effect': hit a button on the remote control unit, and the corresponding knob on the panel starts to rotate! However, this would involve a difficult and expensive mechanical system, so we settled on an electronic (infra-red) version. For top-quality-philes: the unit can be omitted or, if it is included, cancelled.

Loudspeakers

When did we last publish a loudspeaker design? Way back! Why haven't we published one since? Because loudspeaker design is a specialised art — it's much easier to design a bad one than to create something really good! — and because manufacturers have a provided several good designs for the home constructor.

Even so, we felt that the XL range ought to include one or more designs for this all-important component. At present, we have several interesting and promising possibilities in the pipe-line. But we haven't seen or heard any of them yet, so we are very reluctant to make any firm promises. Suffice it to say: if and when we publish a design, rest assured that it comes from a reputable specialist in this field!

FM tuner

We haven't even thought of a 'musical' name yet! What we have in mind should be revolutionary; in fact, 'in-house' it has been dubbed the FM-2000. High performance, easy to operate, microprocessor-controlled . . . Wait and see!

XL

Why did we call this the Elektor XL range? What does XL mean? An honest answer: we don't know, but it sounds nice! We picked those letters six months ago, because they have a nice high-quality 'sound', and we can't prove our brains ever since for a good explanation. 'Excellent'? 'Extra Luxury'? 'Exclusive'? Forget it! It's simply a series of audio gear that we'll be describing from now until . . . then.
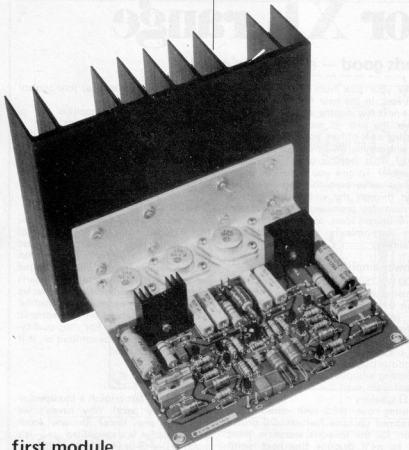
**first module
in the audio XL range**

crescendo

first module in the audio XL range

Power MOSFETs are available as P-channel and N-channel types. This makes it possible to design a class B amplifier in which both types operate with 'time sharing' — to borrow a term from the computer field. Since there are limits to the power rating of such a MOSFET, we have used what could be described as double 'job sharing' in this design: an output stage with two N-channel and two P-channel MOSFETs. The result is an output stage capable of great output power and exhibiting extremely low distortion.

The principle

If one takes a passport photograph and folds it downwards in the middle, over the nose and between the eyes, the two halves will certainly not be identical. The same applies to many amplifier designs. In our case, of course, we are less interested in the visual distortion than in the harmonic and non-harmonic distortion as a result of non-symmetrical amplifier design. These types of distortion can be avoided by proper, symmetrical design of the circuit.

The reason is as follows: the distortion of even harmonics produced on each side of the symmetry line finally cancel each other out (as AC voltage into the load impedance). The result is less 'cosmetic circuitry' in the form of feedback or other alternatives, in order to meet the high requirements for quality of the output signal. Since the medicine (feedback) is usually worse than the malady (lack of stability, dynamic distortion (TIM), it is a good idea to try to avoid the ailment and reduce the dose of medicine.

Let us return to the analogy of the passport photograph. Looking at the block diagram of figure 1 or the circuit diagram of figure 2, if we draw an imaginary line along the middle we can see that each component has its counterpart. Components which are only present once are assigned to the common input or output (including feedback). There is one exception: we only need one trimmer potentiometer (P1) to set the quiescent current.

The input circuitry in figure 1 begins with a highpass filter consisting of R1, C1 and C2. This filter is necessary for two reasons: firstly, to prevent very low frequencies from reaching the bass loadspeaker, and secondly to block any DC that may be present at the input. Any DC component would appear at the output and unbalance the quiescent current setting of the output stage. The lowpass filter consisting of R2 and C3 was designed to pass signals with frequencies of up to approximately 160 kHz.

The double differential amplifier consisting of T1...T4 is represented with two operational amplifiers in figure 1. The output signals of the two differential amplifiers (voltage over R11 and R13) result from the comparison between the input signals and the output signal attenuated by R4, R5 and R6. In other words, the feedback
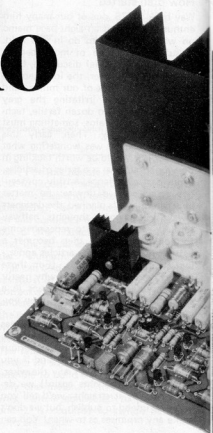
effect is contained in the voltages over R11 and R13. For AC voltages the amplification is 1 + (R5/R6)/R4 = 32. For DC voltages the amplification is 1. This is catered for by C4 and C5. Without these two capacitors, the offset of the double differential amplifier would also be amplified by a factor of 32.

This offset consists of the different base-emitter voltages at the given collector currents and of any difference that may be present between the voltage drops over R1 + R2 and R5/R6 (resulting from the base currents of T1/T3 and T2/T4 that may not be equal). However, this last contribution to the offset voltage can be ignored if R1 and R2 are equal in value to R5 and R6 in parallel. This explains the apparently unnecessary parallel connection of 39 K and 150 K instead of one 33 K resistor. Ideally, the current flowing from the base of T3/T4 will be as great as that flowing into the base of T1/T2. In this case the voltage drops are zero. Incidentally, this article also explains how the low output offset of +20 mV can be reduced even further.

The current source 'supply' (T5, T6) turns the input stages into good differential amplifiers and poor analogue adders: amplification and non-linearity (excluding the feedback effect) for common signals are low. The influence of slow and rapid variations in the operating voltages (100 Hz hum plus
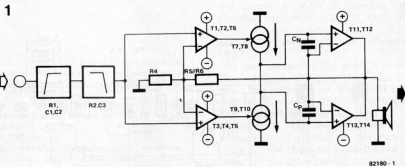
Figure 1. 'A line along the centre': the block diagram of the power amplifier shows the symmetrical arrangement.

sinusoidal halfcycles at the signal frequency) on the desired signal is zero squared. One more comment on the differential amplifiers: R12 and R14 ensure that the collector-emitter voltages of T1 and of T2 and those of T3 and T4 are almost identical. In this way, thermal balance between the two differential amplifiers is achieved, resulting in a favourable effect on the offset.

The differential amplifiers supply the drive voltages (via R11 and R13) for two current sources: the sources of the drive current for the output stage consisting of T11 . . . T14. Each of these current sources consists of a cascade circuit of two transistors: T7 and T8 at the top and T9 and T10 at the bottom. This apparently unnecessary duplication of components provides many advantages. Each cascade forms a 'super transistor' with a current amplification factor of at least 400 and with a straight and almost flat I_C (U_{CE}) characteristic extending up to collector voltages of 250 V, and with an equally linear, frequency and voltage-independent collector-base capacitance of a few tenths of a picofarad, which can be made as small as the p.c.b. layout will permit. What we have is an ideal, textbook current source for frequencies from DC to 0.5 . . . 1 MHz. How is this achieved? There are two contributing factors. the first is 'job sharing'. This high current amplification is provided by T7 and T9, operating at low level (a few volts), whilst T8 and T10 handle the high voltage and dissipation. The current amplification of T8 and T10 can be ignored, because the currents flowing in their emitters are almost 100% equal to those flowing in their collectors. The second factor is screening. Two parallel, metallic surfaces present a capacitance. Now what if this capacitance is undesired? The simple solution is to take a third metal surface and place it between the other two. This third surface eliminates the original capacitance and creates two new, considerably lower and less harmful capacitances. In figure 2 the base of T7 and (T9) forms one electrode, the collector of T8 (T10)

forms the other electrode and the base of T8 (T10) forms the intermediate electrode.

Why is this screening so important? The 'eliminated' collector-base capacitance in this amplifier is present anyway (a few picofarads) and it is non-linear. One can imagine it as a varicap diode with a capacitance which is greatly dependent on the inverse voltage. In many amplifier designs this non-linearity is cured by connecting a capacitance in parallel which is 50 to 100-times greater. This Miller capacitance, as it is known, also serves as a stabilizing capacitor. The solution is not optimum, however. It is better to avoid capacitance altogether, no matter how linear it may be!

The collector-base capacitances of T8 and T10, which are special video transistors, are very low. This capacitance (2 x approximately 2 pF) is effectively between collector and ground and cannot cause any mischief. However, this cascade solution has its price: the dynamic range of the output stage is restricted as a result of the necessary DC voltage setting. But this does not present a problem because it is better for the top end of the dynamic range to be restricted by the cascade circuit than by the saturation phenomenon in the output stage itself. This in turn has a favourable effect on recovery after an overload.

The DC voltage setting of the cascades and of the differential amplifiers is performed by zener diodes D1 and D2, which are connected to the operating voltage via R17 and R18. The result of this 'joint operation' of the zener diodes with C8 . . . C11, R19 and R20 is that the DC setting of T1 . . . T4 does not change in the slightest (in the event of operating voltage variations). Let us now consider the output stage. It can handle a peak current of 14 A and a dissipation of 320 W at 50°C. Short-duration current limiting is performed by D3/D5 and D4/D6. In the event of long-term overcurrents, fuses F1 and F2 ensure the necessary shutdown.

The output stage is adjusted to a

2

Figure 2. Circuit of the Crescendo power amplifier showing the test points.

quiescent current of 2-times 100 mA. This current is more than adequate to provide sufficient 'overlap' (simultaneous conducting) of the two output-stage halves to keep any distortion (that might arise from insufficient or even no quiescent current) at a very low level. With drain currents upwards of about 100 mA, this current decreases as the temperature rises at a constant gate-source voltage. This negative temperature performance of the MOSFETs ensures that the output stage cannot overheat. With conventional NPN/PNP output stages, certain measures must be taken to prevent this hazardous situation. No such measures are required with our design. It is merely necessary to set the quiescent current

with P1. No additional diodes and transistors are needed.

The MOSFET output stage exhibits a considerably flatter output current/input voltage characteristic than that of a conventional output stage. This results in advantages and disadvantages. Let us first consider one significant disadvantage. The output stage is configured as a complementary source-follower. This means that maximum drive is determined by the operating voltage less the drive voltage. Since the drive voltage for MOSFETs must be higher than normal with the same AC output voltage, the result is a reduced dynamic range at the given operating voltages (a further restriction is created by the voltage drop over the relatively high saturation

resistance of a MOSFET).

Now let us look at the advantages. By its very nature, the flatter voltage-in/current-out characteristic provides less opportunity for static and dynamic distortion. Furthermore, a particular quiescent current can be adjusted with P1. There is no jump from 0 to about 1 A when the quiescent-current trimmer is rotated by 10°. The MOSFET output stage T11...T14 can handle high frequencies as well as high output power. The relationship between output current (drain current) and input voltage (between gate and source), i.e. the slope, remains unaffected by the frequency right up into the megahertz region. However, this can also result in a tendency to oscillate. The risk of

Table 1. Technical data

General:	• Fully symmetrical/complementary hi-fi MOSFET output stage
	• Good dynamic characteristics because the internal 'inertia' of the *input* is utilized for full frequency compensation (designed for unconditional stability).
Output power	• 140 W into 8 Ω when both channels are simultaneously driven at a distortion factor which does not exceed 0.01% (−80 dB) within the frequency range 20 Hz . . . 20 kHz. Total power output: 280 W.
	• 180 W into 4 Ω when both channels are simultaneously driven at a distortion factor which does not exceed 0.01% (−80 dB) within the frequency range 20 Hz . . . 20 kHz. Total power output: 360 W.
	• 180 W max. per channel into 8 Ω (fully driven)
	• 250 W max. per channel into 4 Ω (fully driven)
Input sensitivity	1 Vrms for 130 W in 8
Input impedance	25 kΩ
Frequency range	4 Hz . . . 160 kHz + 0/− 3 dB (with a source impedance of 600 Ω).
Attenuation factor	100
Output offset voltage	Less than ± 20 mV DC
Extras	• DC output protective circuit, combined with activation delay
	• Temperature sensor for heatsink
	• VU meters

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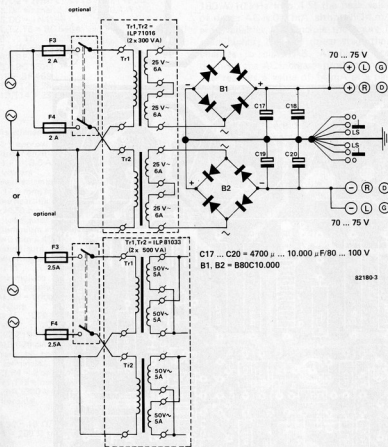
Figure 3. This is the hefty power supply for the amplifier.

oscillation is largely avoided by keeping the wiring as short as possible, decoupling capacitors (C6, C7, C14 and C15), limiting resistors (R23 . . . R26) and, with somewhat less influence, (R27 . . . R30).

The two capacitors C_N and C_P in the block diagram of figure 1 represent the input capacitances of the MOSFETs. Over the operating range of the amplifier, the voltage over C_N and C_P is independent of the frequency and relatively proportional to the output current. The frequency-dependence is based on the drive current delivered by the driver stages T7 . . . T10, which rises with the signal frequency and/or the output current. However, this drive current is none other than the charging/discharging current of C_N and C_P.

The result of having a current that rises with frequency is that the voltage over R15 (R16) also increases with frequency. The same applies to the voltage over R11 (R13). The advantage of this arrangement soon becomes clear. In all amplifiers with feedback, the so-called open-loop gain (= gain *without* feedback) must drop with increasing frequency, as of a particular point. The drop must be such that the frequency rolloff at which the open-loop gain is one is not quite 12 dB per octave, i.e. just before the point of causing a 180° phase shift. This is not an invention of Elektor, but was established by two gentlemen called Bode and Nyquist some time ago.

This not-quite-12 dB, not-quite-180° situation characterizes the stability minimum. If one wishes to remain in the safe region of 6 dB per octave and 90° phase shift, in order to allow capacitive loads or capacitive contents of loads (crossover networks), the open-loop gain must roll off with 6 dB per octave from a 'safe' frequency onwards (which is now considerably higher). In all cases this must be up to the frequency at which the amplification has become one, but beyond that point if possible. The maximum open-loop phase shift in this case is 90° in the quiescent state; the system is unconditionally stable. It is almost always necessary to create these conditions by affecting the open-loop gain, i.e. by providing *compensation*. In most cases this is accomplished by inserting a compensation capacitor.

With our circuit, however, this is unnecessary. If the open-loop gain decreases with 6 dB per octave from a safe frequency onwards, there is a point in the amplifier at which the drive voltage or current increases with 6 dB per octave at a given drive level. We have already found this 'point': the drive current through C_N and C_P, or the drive voltage over R11 and R13 which amounts to the same thing. To put it another way: the frequency-dependent *input* characteristic of the MOSFET output stage T11 . . . T14, which is present in any case, is used for

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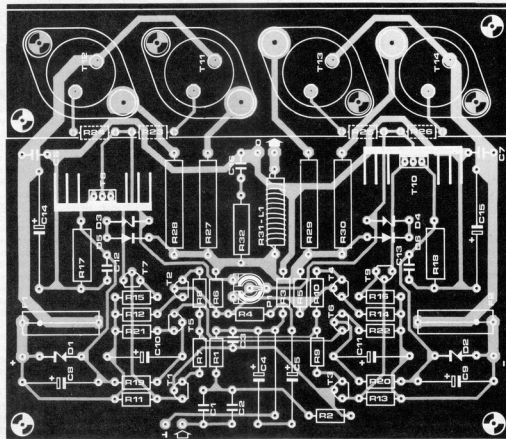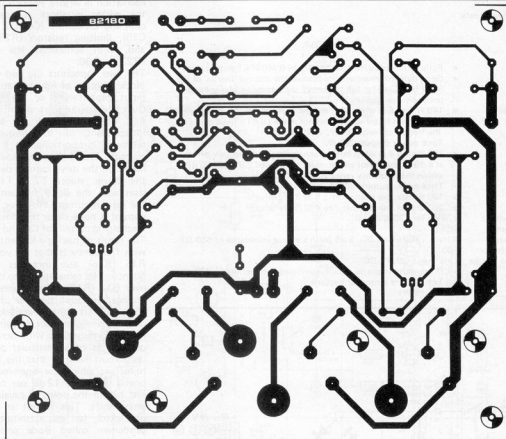
Parts list

Resistors:
R1 = 27 k
R2 = 3k9
R3 = 10 Ω
R4 = 1 k
R5 = 150 k
R6 = 39 k
R7...R10 = 150 Ω
R11...R14 = 6k8
R15,R16 = 82 Ω
R17,R18 = 10k/1 W
R19,R20 = 2k2
R21,R22 = 5k6
R23...R26 = 220 Ω
R27...R30 = 0,22 Ω/5 W
R31 = 1 Ω/1 W carbon film
R32 = 10 Ω/1 W carbon film
P1 = 250 Ω preset

Capacitors:
C1,C2 = 820 n MPF*
C3 = 220 p ker.
C4,C5 = 220 μ/10 V
C6,C7 = 220 n MPF*
C8...C11 = 100 μ/10 V
C12,C13 = 330 n MPF*
C14,C15 = 100 μ/10 V
C16 = 22 n MPF*
*MPF = metallized plastic foil

Semiconductors:
D1,D2 = zener diode 3V9/0,4 W 5%
D3,D4 = zener diode 12 V/0,4 W 5%
D5,D6 = 1N4148
T1,T2,T6 = BC546A
T3...T5 = BC 556A
T7 = BC560C
T8 = BF 470
T9 = BC 550C
T10 = BF 469
T11,T12 = 2SK135 (Hitachi)
T13,T14 = 2SJ50 (Hitachi)

Miscellaneous:
L1 = approx. 2 μH, 2 × 10 turns
Copper enamel (dia. 1mm) on R31
F1,F2 = 3.5 A fuses, slow-blow, with p.c.b. fuse holders
Two heatsinks for T8 and T10 (e.g. SK09/37.5 mm; approx. 8.5 °C/W)
One heatsink for T11...T14 (e.g. SK53/>150 mm, black anodised, not predrilled (see figure)
Aluminium angle section
40 mm × 40 mm, 180 mm long (see figure and figure)
Mounting and isolating hardware for T11...T14 (see figure)
Thermolube
Power supply (without printed circuit board):
B1,B2 = bridge rectifiers 100 V/25 A (see figure)
C17...C20 = 4700...10000
μ/80...100 V
C17,C19 = 10000 μ/80...100 V;
C18,C20 can then be ignored.
Preferably can electrolytics with screw terminals.
F3,F4 = 2 or 2.5 A slow-blow fuses
Tr1,Tr2 = mains transformers 2 × 25 V/6 A (300 VA) or 2 × 50 VA (500 V) toroidal

R 32 = 10 Ω/1 W carbon film
P1 = 250 Ω trimmer potentiometer

Figure 4. Track pattern and component overlay for the power amplifier. The four MOSFETs are also situated on the p.c.b. This is not the simplest solution but certainly the most reliable one.

purposes of frequency compensation. We can be greatful for the very high, overall collector impedance of the cascade T5...T10 which makes this possible.

Why is this advantageous? The 'inertia' of C_N and C_P is present in any case, whether it is used for compensation or not. The alternative would be complete or additional compensation elsewhere in the amplifier. This would mean that a Miller capacitance would have to be added to the circuit of Figure 2. It would provide additional 'inertia' but would also give rise to TIM problems. Let us assume that such a capacitor were present between the base of T7 (T9) and the collector of T8 (T10). The maximum available charging/discharging current is approximately 300 μA (collector current of T1 or T3). Clearly there will be an audible frequency at which a 'clean' sinewave at the input will result in an equally 'clean' triangular waveform at the output... Fortunately, that is not the case with our design.

Those readers who are interested in the slew rate can rest assured that the amplifier does not easily become unstable, in other words it would take a great capacitive load at very high frequencies. With 180 W/10 kHz into 4 Ω the peak value of driver AC is 0.6 mA, although 14 mA are available. In principle the figure is even higher, but the driver stage then changes to class AB. At higher frequencies the AC increases proportionally and reaches a value of 14 mA at a particular frequency. However, the input filter consisting of R2/C3 then becomes effective.

Let us briefly consider some of the components which serve to stabilize the circuit. Firstly, R32 and C16 which are rated so that R32 does not go up in a puff of smoke when the amplifier is tested at full output with 100 or 200 kHz. Because of the high self-inductance, R32 must not be a wire-sound resistor. L1 and R31 in parallel partially or fully compensate for the phase shift caused by a capacitive load at the amplifier output. R31 serves for damping the resultant LC circuit so that square-wave reproduction is faithful in this case too.

That completes the description of the output stage. The amplifier requires a power supply to power it from the mains. The power supply is shown in figure 3 and is rated for stereo operation. One transformer and one bridge rectifier are required for each operating voltage. Two channels are provided with a common positive and negative rail. However, there is no risk of crosstalk between the two channels, and certainly not via the power supply. As already mentioned, interference to the operating voltages does not impair operation of the amplifier. It is preferable to use toroidal transformers in the power supply. The constructor can choose between a medium-rating power supply (600 VA) and a high-rating power supply (2-times 500 VA). The choise depends

on the amound budgeted and on whether the amplifier is going to be 'pushed' into a load of 4 Ω. The DC smoothing also requires a little thought. The minimum is 4700 μF and the maximum is 10000 μF per operating voltage and per channel. The maximum values for C17...C20 are not only governed by the cost, but are also a matter for technical consideration. The 'bigger' the capacitors, the lower is the 100 Hz hum and the greater are the charging current peaks.

The technical data in table 1 apply to the medium-rating power supply with minimum smoothing.

When the amplifier is switched on, the output voltage will initially contain a DC component. This is because the feedback is not immediately effective. Also, electrolytic capacitors C8 and C9 require a certain time before they are charged up to the zener voltage of D1 (D2).

There is one more situation in which the DC voltage can be present at the amplifier output: this is in the event of an overload on the output stage, if fuses F1 and F2 do not blow or do not blow simultaneously. This voltage and the 'starting voltage' already mentioned can be hazardous to our expensive loudspeakers. For this reason it is a good idea to equip this amplifier with a DC protection and activation-delay circuit, which is also suitable for other amplifiers. For reasons of space, we will discuss such a circuit in the next issue of the magazine.

Construction

When wiring an amplifier to its power supply it is easy to make mistakes that can impair the audio performance. We therefore recommend that the following text and the corresponding illustrations be followed closely.

One difficulty has already been removed: figure 4 shows a printed circuit board layout. The cost of this p.c.b. is negligible compared to that of the power supply and the MOSFETs. For this reason we strongly recommend that only this p.c.b. be utilized. Even very slight interaction between the output and inputs of the cascades on the one hand and the 'wiring' of the MOSFETs of the p.c.b. on the other hand are critical.

The method applied to position the MOSFETs directly on the p.c.b. is not the simplest way, but has proven to be the most reliable one. Although a few holes have to be drilled in a heatsink for the transistors, this is far preferable to positioning the MOSFETs on a heatsink away from the p.c.b.; the resultant wiring would very probably cause the output stage to oscillate. Our arrangement may be unusual, but it is much more reliable. Those familiar with Murphy's Law will know that 'Amplifiers always oscillate, oscillators often fail to oscillate'.

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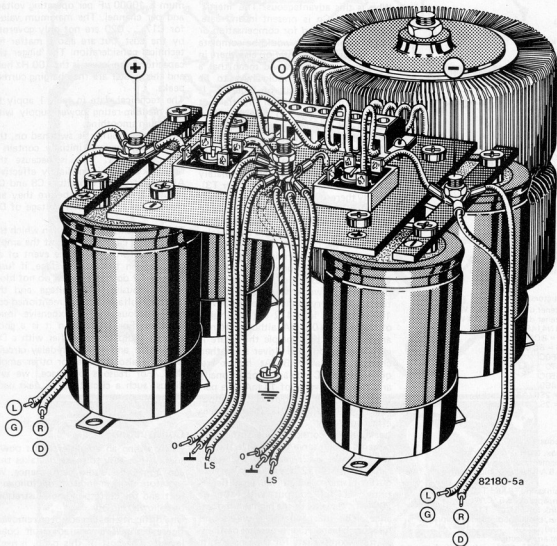
Figure 5. A possible power supply arrangement.

We shall tackle the mounting of components on the p.c.b. first. All components are inserted except for T11 . . . T14 and R23 . . . R26. R27 . . . R30 must have a little clearance from the p.c.b. when soldered in. This provides the resistors with some cooling. The enamel must be carefully removed from the ends of coil L1 so that a good electrical connection is made with R31 when soldering. As soon as P1 has been inserted, it should be rotated fully anticlockwise to avoid any problems later.
If the amplifier is to be trimmed to minimum DC output offset (more about this later), it is better to use transistor sockets for T1 . . . T4, and insert the transistors later.

The heatsinks for T8 and T10 (see figure 6b) are positioned vertically. The heatsink for T10 must not make contact with the lead of C7 which is very close to it. It is advisable to try this out visually before drilling a mounting hole for T10 in its heatsink.
We must not forget the wire link (input ground). On the component side, the pins of T1 . . . T7 and T9 should not be longer than 4 mm. We now turn to the positioning of T11 . . . T14, T23 . . . R26 and the heatsink. First the aluminium bracket is cut to the width of the p.c.b. and then the holes are drilled. This can be done in two ways. When the two mounting holes have been drilled, the aluminium bracket and the p.c.b. can be

bolted together and the p.c.b. can be used as a drilling template. Otherwise the drilling diagram in figure 6c should be used. Some precision is required here; T11 . . . T14 must be installed in a fully isolated fashion. A poor fit can cause short-circuits between the metal parts. Finally, the aluminium bracket is mounted on the p.c.b. together with the MOSFETs as shown in figure 6c. It is better to apply too much rather than too little thermolube to each side of the mica insulation. When the assembly is finished, use another ohmmeter to ensure that there is no contact between the TO-3 and the aluminium.
Mechanical assembly is then followed by electrical installation of transistors

180

150

optional

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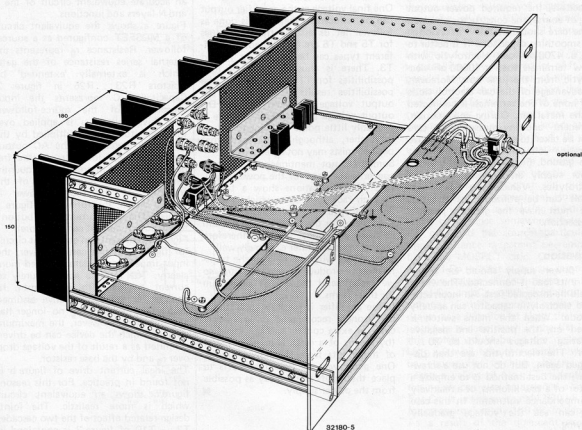
An overview showing the assembly consisting of the p.c.b., MOSFETs, bracket and heatsink and some practical details ...

T11 ... T14. The gate and drain terminals are simply connected to the appropriate tracks on the soldering side. A solder lug is required for each source terminal. T11 and T12 are the furthest from the right-hand edge of the p.c.b. and T13 and T14 are the closest to it (as in figure 4).

Resistors R23 ... R26 are drawn with dashed lines in the component overlay of figure 4. They are positioned as closely as possible to the gate terminals of the MOSFETs on the soldering side. There are no mounting holes. The leads of the resistors are cut as short as possible (1 cm maximum), then bent and soldered to the copper surfaces, leaving a clearance between the resistors and the p.c.b.

The p.c.b. with components fitted is now connected to the large heatsink (see figure 6b). The manner in which the two units are assembled largely depends on the housing. Since the heat dissipated by the MOSFETs is transferred to the heatsink via the aluminium bracket, extremely good contact is required between the two. At least six nuts and bolts (M4 x 15, for example) and a generous amount of thermolube between the two metal surfaces will ensure good thermal contact.

If a stereo amplifier is desired, the entire procedure must be repeated.

The housing and power supply are the largest parts of a power amplifier.

Figure 5 shows a suggestion for the complete stereo power amplifier. The additional circuitry mentioned is not yet included. However, the wiring will not be greatly changed by adding these extra circuits.

The wiring is fairly critical. Performance of the amplifier can be greatly impaired by accidental metallic contact or inductive or capacitive pick-up. A likely source of interference is pick-up from the operating voltage leads at the input. If the amplifier is driven with a strong sinusoidal signal, the two supply currents look like half-wave rectification with many harmonics. The higher the harmonics, the greater the likelihood that they will be picked up at the input.

Accidental metallic contact is prevented by only having one ground point (at the electrolytic capacitors). The amplifier is provided with an input ground and an output ground which are interconnected internally via R3 and connected externally to the main ground point.

The rating of the power supply depends on various factors: the transformers chosen for Tr1 and Tr2, the smoothing capacitors, the required power output and, of course, the constructor's budget. Some care should be taken in choosing the smoothing capacitors. It is better to use a 4700 μF can electrolytic with screw terminals than a 10000 μF electrolytic from the junk box. Moreover, an advantage of the can electrolytic is that none of the terminals is connected to the metal can. During construction, alignment and any measurement, care must be taken to ensure that the negative operating voltage never makes contact with ground. Figure 5 shows a possible power supply arrangement using can electrolytics. Vehicle-type spade terminals can be utilized. The stranded wire must have the greatest possible crosssection.

Activation

The power supply should be tested before its load is connected. The wiring should be inspected first. An incorrectly wired electrolytic capacitor can actually explode! When the mains switch is turned on, the positive and negative operating voltages should be 70 . . . 75 V. The electrolytics are then discharged again. But do not use a screwdriver; the best method is to employ a resistor of a few kilohms, or a relatively low-impendance voltmeter. In this case one can see the voltage gradually decaying.

The entire amplifier can now be tested. If the stereo version has been built, the instructions in the following text must be followed twice.

First, position all ground leads as shown in the figures and as described. The positive and negative leads from the power supply are then connected to the output stage. Use two 10 Ω, ¼ W resistors temporarily instead of fuses F1 and F2. Quiescent-current trimmer P1 is rotated fully anti-clockwise. The loudspeaker terminals remain disconnected. Now switch on the power supply. Should there be a short-circuit somewhere in the output stage, the 10 Ω resistor will go up in smoke. In this case, switch off the amplifier, find the fault and correct it and insert two new resistors.

When everything is in order, connect a multimeter over one of the resistors (3 V or 6 V DC range, see also figure 2, F1 and F2). The voltage over this resistor should be zero. Otherwise P1 is not at its extreme anti-clockwise setting. The voltage should rise as P1 is slowly rotated. At the setpoint voltage of 2 V, the current through this resistor is

200 mA, i.e. 100 mA per MOSFET. When this adjustment has been made, switch off the amplifier and insert the two fuses F1 and F2. Switch on again and measure the voltage between the amplifier output and ground. It should not exceed 20 mV (positive or negative).

The amplifier is now ready for operation. The test points marked in figure 2 can now be checked.

One final voltage at the amplifier output can be reduced further. This is done as follows: let us assume that the values for T5 and T6 are established. Two different types can be utilized for T1 and T3. There is thus a choise of four possibilities for T1 . . . T4. One of the possibilities results in the lowest DC output voltage. However, if the DC output voltage is only 20 mV, there is probably little point in trying to reduce it further, although we suspect that perfectionists may not agree with us.

Something not mentioned up till now concerns the case for the power amplifier. The illustrations show a typical 19 inch rack type case, which is ideal. Some of you may be tempted to use steel plates for the sides top and bottom as these are robust and will therefore protect your amplifier extremely well.

Steel reacts with the field of the transformers to produce quite a loud hum, so we recommend the use of aluminium for these items.

If the amplifier is for P.A. applications we strongly recommend using a larger case for extra cooling and the shielding (by means of a small aluminium plate) of the inputs from the power supply. One good way to help matters is to place the inputs as far away as possible from the power supply. ◀

Literature:
Toroidal Transformers
Elektor April 1982
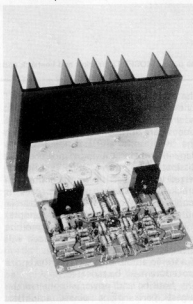
Equivalent circuits

MOSFETs as source-followers

When MOSFETs are utilized in output stages, the P and N-layers and junctions are of less interest than the performance of a combination of resistors, capacitors and voltage or current sources. When considered as a whole, these provide an accurate equivalent circuit of the P and N-layers and junctions.

Figure a shows the equivalent circuit of a MOSFET configured as a source-follower. Resistance r_g represents the internal series resistance of the gate, which is externally 'extended' by resistors R23 . . . R26 in figure 2. Capacitance C represents the input capacitance of the source-follower. The drive voltage u is applied over this capacitor; when multiplied by the slope S, it determines the AC output current through load R$_L$. In the frequency range of interest, S (frequently denoted Y_{fs}) is independent of the frquency. If the source-follower is voltage driven, the formula of figure a applies. The gate current contribution to the output current can be ignored.

Figure b represents an equivalent circuit for figure a. In this case, however, the input impedance is demonstrated more clearly. The formula applies purely to current driving with a current i. In contrast to the voltage drive assumed in figure a, resistance r_g no longer has any influence. However, the maximum level to which the device can be driven is limited as a result of the voltage drop over r_g and the base resistor.

The ideal current drive of figure b is not found in practice. For this reason, figure c shows an equivalent circuit which is more realistic. The joint, design-related effect of the two cascades T7 . . . T10 of figure 2 is contained in the current source i_s and resistance R. R represents the joint collector resistance of T8 and T10. The formula exhibits a certain frequency-dependence which leads to the automatic, inherent frequency compensation for unconditional stability as mentioned in the text. The necessary rolloff of 6 dB per octave is found in the relationship between the output voltage and the sum of the cascade input voltages.

A given open-loop gain is associated with a particular cutoff frequency W_{3dB}. The higher the one value, the lower is the other. The fact that the frequency compensation of the amplifier can take place entirely in the combination of driver stage and output stage (i.e. no other capacitors are required, with all their disadvantages), results from the use of the cascade circuitry. The circuit provides a high resistance R and ensures that no series capacitance is connected between output and inputs. Incidentally, if true current drive were utilized as assumed in figure b, the total effect of the driver stage and output stage would be an integrating one. We would then have a cutoff frequency

a

$$\frac{u_o}{u_i} = \frac{SR_L}{1 + SR_L} \cdot \frac{1}{1 + \dfrac{1}{1 + SR_L}}$$

82180 - a

b

$$\frac{u_o}{i} = \frac{SR_L}{1 + SR_L} \cdot \frac{1}{pC}$$

82180 - b

c

$$u_o = i_s \frac{SR_L}{1 + SR_L} \cdot \frac{R}{1 + \dfrac{R + r_g}{1 + SR_L} C}$$

$$\omega_{-3dB} = \frac{1}{(R + r_g)} \cdot \frac{C}{1 + SR_L} = \frac{1}{RC} \qquad (r_g \ll R)$$

$$i_s = \frac{u_i (T7)}{R15} = \frac{u_i (T9)}{R16}$$
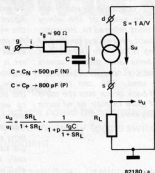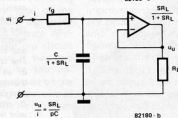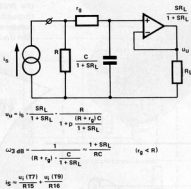
82180 - c

d
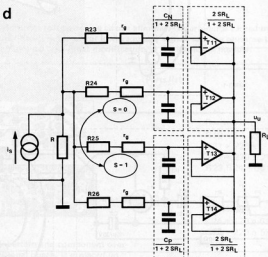
82180-d

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of 0 Hz. Of course, this would not be satisfactory. Suppression of distortion and interference, effective as a result of the feedback, must be frequency-independent over the largest possible frequency range.

So far we have only dealt with one source-follower (fugures a . . . c). In reality, however, there are four such devices (T11 . . . T14 in figure 2.) Hence the equivalent circuit of figure d. At low drive, all four MOSFETs conduct; at high-level drive, either T11 and T12 or T13 and T14 conduct.

In figure d the time constant $1/W_{3dB}$ is established by the product of R and parallel connection (sum) of the four capacitors. It should be noted that if two MOSFETs turn off and the other two conduct, there are two small capacitances (i.e. the 'conducting' capacitances for which $S \gg 0$) and two large capacitances pertaining to the MOSFETs which are turned off. Capacitance C_N is not exactly equal to C_P. This means that the output stage is not fully symmetrical. However, there is no point in inserting the differential capacitance somewhere between the gate and the source, particularly since resistance r_g cannot be removed from the MOSFET chip. Capacitances C_N and C_P exhibit a strange response. At low values of gate-source voltage U_{GS}, C_N and C_P greatly depend on this voltage. If their response curves were drawn as a function of U_{GS}, the result would be a deep notch in the flat line: this notch would be in the region of $U_{GS} = 0$, whilst the characteristic would be almost flat at high positive and negative values of U_{GS}. The depth of the notch can also be assigned a value. For C_N it is approximately 270 pF and for c_P approximately 160 pF 'in depth'. As a result of the quiescent current setting, these two characteristics shift in such a way that the notch becomes more of a 'ditch' which is almost horizontal at the bottom. This means that as of a particular drive level, the driver stage must not only supply or draw the 'normal' current i = C x dU/dt but also the current U x dC/dt. This performance can be observed with an oscilloscope connected over R15 or R16 (the oscilloscope chassis must be floating), with a high drive level and by adjusting the quiescent-current trimmer P1. The practical, negative results for linearity at high-level drive and high signal frequencies can be ignored. However, we should point out that the problem can be solved by using three MOSFETs for each half of the output stage. The changes in U_{GS} (i.e. the six AC voltages u over C in figure a) are then only effective at the bottom of the wide 'ditch'.

home telephone help

used (see figure 1a) may differ depending on the type of telephone in use. If your system is already operating, you will already be aware of the wiring connections referred to. However, if in doubt, the easiest method of checking is to undo the handset microphone and speaker covers and make a note of the colour coding used. This can then be tracked back down into the main body. Figure 1a may be of some assistance here.

In order to prevent the possibility of feedback the connections to the speaker should be exchanged (reversed phase) as shown in figure 1b. The power supply for the mini line amp is derived from the microphone line as a dc voltage exists at this point when the handset is lifted. The emitter of T1 is connected to the negative line while resistor R2 is connected to the positive. Care must be taken to ensure that connections here are correct.

Readers have advised us of problems encountered with the use of old surplus type telephones. Basically the pulses generated by the dialling mechanism (in certain cases) are incorrect and the extension dialled fails to respond (no ring out). In the normal course of events, when the hand-set is lifted and the dial is turned the speech line is shorted to earth by means of an internal switch within the dialling mechanism, in effect you cannot hear what is going on. By disconnecting the appropriate wire from the mechanism (modern telephones it is blue) should solve the problem. You will then hear through the speaker the dialling pulses and eventually the extension dialled ringing.

technical answers

Speak up, you're through!

This short article is aimed at those readers who have found a use for the home telephone published in the September issue of Elektor. Some readers have expressed a desire to improve the volume level of the speaker in the handset. There is one, very quick and easy answer to this problem. This simply consists of replacing R6 on the printed circuit board of each extension with a wire link. This will serve to increase the output level but, in this case, simple is not quite the best! Unfortunately, the quality of the speech signal can suffer badly. Our good friends at British Telecom are able to use line amplifiers to retain speech quality (we have this on good authority!). This answer is not available to us unfortunately, since the cost for the complete system would probably treble. We do have an answer though!

The modification we have arrived at entails the addition of a single transistor amplifier stage (a sort of mini line amplifier). One of these is needed in each extension. The circuit is very small, physically, it can be assembled on a piece of Vero board measuring only 2 x 2 cm.

Figure 1b illustrates how the mini line amp can be fitted into the handset of the extension. Obviously the tag numbering system

82193-1

82193-2

Soft switching

improvement to the High Com

based on information from the Telefunken Television and Radio Company, Audio Development

In case the title of this article could be misinterpreted, the purpose of this circuit is not to replace the noisy toggle switches that are typically used in home-made equipment.

This modification provides soft switching by changing the response time of the HighCom circuit to increase the decay time, thus eliminating interference. With this modification the HighCom circuit becomes even better than it was and Telefunken will be offering the improved version as an integral part of the circuitry in future. The HighCom circuit was further refined in the Telefunken development laboratory. The result is an improvement in the form of the auxiliary circuit in figure 1. The track pattern and component layout are shown in figure 2, but we shall discuss this later. These are the improvements:

1. The distortion factor at frequencies of about 20 Hz is reduced by two thirds. The compander distortion thus becomes noticeably less than band distortion in the audible range. To quote actual figures: the distortion content of the first harmonic of a sinusoidal 20 Hz signal is reduced by about 6% and that of the second harmonic 3.5%. The total distortion factor with the new version is only 3.31%, compared to 10.38% with the old version. The improvement was achieved by increasing the decay time which is effective during the holding time.

2. Interference caused by very short pulses, such as electrostatic discharges when playing records, is now eliminated by modifying the response time of the circuit. The network for this function now contains two time constants instead of one. This greatly improves the compander's capability and has been demonstrated by the better response time on a sinusoidal 10 kHz burst.

3. Short drop-outs result in undesirable, audible fluctuations in level. The HighCom circuit sometimes responded to these drop-outs with uncontrolled regulating effects. For example, the loudspeakers sometimes exhibited independent audio levels. On the other hand, the type of noise effects in signal pauses that are familiar with other noise suppression systems could not be heard. Telefunken achieves this performance by controlling the decay with a long time constant during the holding time, followed by a short time constant. However, this automatic changeover between the two time constants was so abrupt that it sometimes resulted in the effects mentioned. Our soft switching circuit eliminates these problems, even with critical signals. There is no doubt that this is a considerable improvement to the HighCom circuit.

The circuit in figure 1 can be constructed on a small vero board or a printed circuit board can be made as shown in figure 2. Terminals 1, 4, 5, 6 and 23 correspond to the pins of the HighCom IC, U401. Solder pins should be inserted at those points. The High-Com module is modified as follows: R6 and C21 are discarded. The value of C7 is changed to 47 n/5% (if this has not already been done). If the module already contains capacitor C7 with this value, the 470 n and 1 k connected in series between pin 1 and pin 6 on the copper track side should be removed. Wire links of about 2 cm in length are now carefully soldered to pins 1, 4, 5, 6 and 23 of the IC. The additional board is then placed on the IC in the HighCom module and the wire links are connected to the solder pins on the printed circuit board.

This completes the modification to the HighCom module and the module can be replaced on the printed circuit board. The result is probably one of the best noise suppression system available.

1
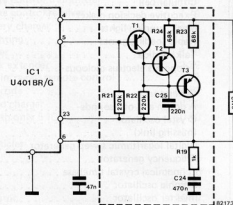
Figure 1. The additional soft switching circuit eliminates interference caused by drop-outs. Additionally, the distortion factor for low-frequency signals and the response time at high frequencies are improved by a slight modification to the HighCom module.

2
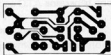
Figure 2. Track pattern and component overlay for the additional board. It is placed on the HighCom IC in the module in piggy-back fashion. When changing components, please observe the specified tolerances. T2 and T3 should have the same specifications if possible.

Parts list

Resistors:
R19 = 1 k 2%
R21 = 220 k
R22 = 220 k 2%
R23, R24 = 68 k 2%

Capacitors:
C24 = 470 n 5%
C25 = 220 n 5%

Semiconductors:
T1 = BC 557
T2, T3 = BC 557B

Literature:
Elektor HighCom, Elektor, March 1981

cumulative index 1982

cumulative index 1982

cumulative index 1982

happy christmas and a prosperous 1983

A theory which has been with us for some time and which is rapidly gaining credence relates to the quantity of negative ions in the air. A high concentration of such ions is both physically and mentally healthy. One element of scientific thought actually states that the quantity of negative ions contained in the air around areas such as St. Moritz is high, which is one reason for the invigorating effect these resorts have on tourists. There certainly seems some truth in these suggestions as negative ion generators are gaining in popularity. Even institutions traditionally known for their ultra-conservative attitude towards new ideas are now using them.

We published a circuit for a domestic ioniser a couple of years ago operated by the mains supply and the idea came to adapt this circuit for use in the car.

The circuit design for a suitable power supply is shown in figure 1. It could be loosely termed a d.c. to a.c. converter. The 555 timer (IC1) produces

7.5 kV. The output is then connected to a sewing needle or something similar.

As most readers already know the electric field strength around a charged body is greatest where the curvature is also greatest, hence a sharp point. An intense field is therefore present at the tip of the needle with electrons being 'sprayed' onto the air molecules negatively charging them. Each batch of negative ions is repelled by the negative charge of the needle point allowing new air molecules to be processed. The result is a constant flow of ions away from the needle which feels very much like a light draught. This in itself will have a refreshing effect upon the driver and passengers without giving consideration to the metabolic benefits of an increased concentration of negative ions.

Keep in mind that apart from generating negative ions the needle will also pro-

in-car ioniser
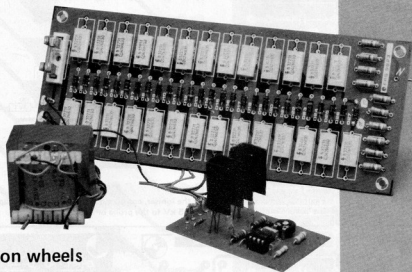
fresh air on wheels

The circuit is one way of increasing the concentration of negative ions in the surrounding air, resulting in improved mental concentration, and reaction speed making roads just that little bit safer. At the very least it will refresh the environment.

a square-wave signal with a frequency around 85 to 100 Hz. The values of R1 and the combination of P1 and R2 have been chosen so that the square-wave produced is symmetrical. This is then fed to transistors T1, T2 and transformer TR1. The result is an a.c. voltage across the two secondary windings of the transformer of approximately 400 V (square wave).

Figure 2 shows the circuit diagram of the ioniser which consists of a 27 stage voltage multiplier, in order to step up the voltage from 400 V to around

duce ozone (O_3). This can on the one hand have certain advantages as it oxidises organic gasses. Carbon monoxide for instance, can be reconstituted into carbon dioxide which is far less harmful. However, ozone if breathed in large quantities can cause irritation of the respiratory system, because of its corrosive and therefore poisonous nature. We therefore do not recommend using the ioniser near to asthma sufferers and please remember that for normal use the ventilation system of the car should be reasonably effective.

Construction

The printed circuit board for the power supply is shown in figure 3. There is nothing critical in the assembly and the only calibration needed is to set P1 to its mid position. No provision was made for mounting the transformer onto the board as the size and type will depend on what is easily available.

Although it is possible by changing C1 for a 330 n capacitor to get a 50 Hz a.c. output, we do not advise it. Basically the peak voltage level produced by the circuit using the specified transformer will be far in excess of 240 V, so that 'blowing up' your razor becomes a distinct possibility. The transistors will need small heat sinks. The transformer should have a 220 V primary and two 6 V secondary windings. Its normal function is reversed in this case.

The printed circuit board and component layout for the ioniser are given in figure 4. Great care is needed to mount the components. Make sure all soldered joints are smooth and neat as any protruding wires or spikes of solder could result in unwanted discharges. This is especially important towards the 'high-voltage' end.

Resistors R1 to R10 limit the current flow in the event of the needle being touched. Lowering the value of these or omitting them is unadvisable as it could result in a fatal shock.

Any sharp needle will do as long as its connection to the printed circuit board is short and rigid. Obviously the needle should point outwards and to prevent accidents a short piece of 30 mm plastic pipe should be mounted coaxially with it. After some use the point will become dirty and possibly eroded, so making the needle removable for cleaning is also a good idea.

Safety first is a good motto to follow when mounting the circuit in the car. Use an insulated box to contain the electronics and position the unit within the car so that it is not a hazard to unsuspecting passengers.   ⊠

Parts list for the power supply

Resistors:
R1 = 1 k
R2 = 47 k
R3,R4 = 470 Ω/⅓ W
P1 = 47 k preset

Capacitors:
C1 = 150 n
C2 = 10 n
C3,C4 = 560 p

Semiconductors:
T1,T2 = BD 139
D1,D2 = 1N4004
D3,D4 = 27 V/400 mW zener
IC1 = 555

Miscellaneous:
Tr1 = 2 × 6 V/0.8 A transformer
2 heat sinks for the BD 139
S1 = on/off switch
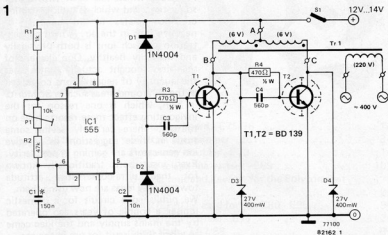
Figure 1. With this circuit the ioniser can be used in the car. With a 12 V d.c. input approximately 400 V a.c. is produced.
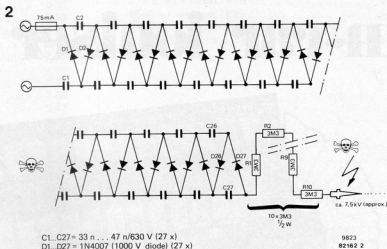
C1...C27 = 33 n ... 47 n/630 V (27 x)
D1...D27 = 1N4007 (1000 V diode) (27 x)

Figure 2. The circuit diagram of the ioniser, consisting of 27 diodes and 27 capacitors. The unit is a voltage multiplier delivering 7.5 kV to the probe or needle.
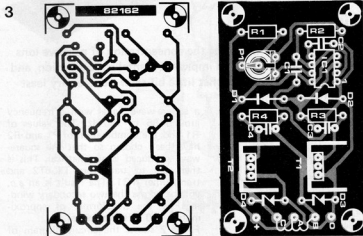
Figure 3. The printed circuit board of the power supply. There is nothing critical in its construction. The transformer uses the 220 V winding as the secondary.

4
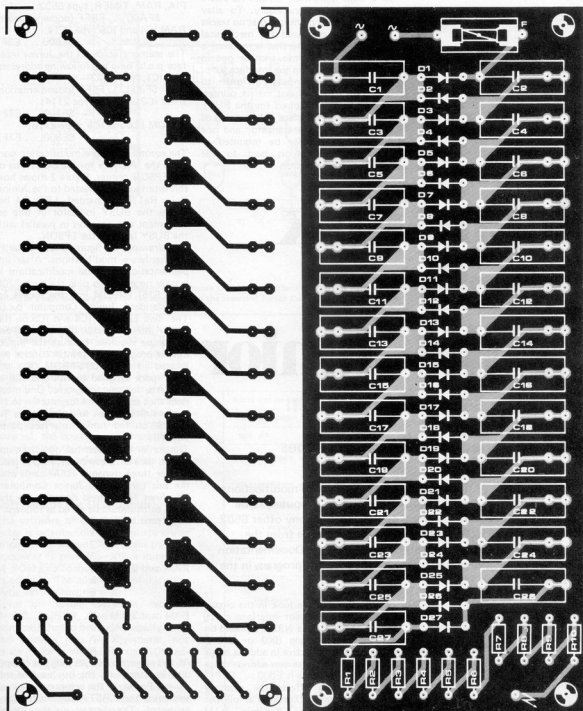
Figure 4. The ioniser board. All the soldered joints and connections have to be smooth and neat in order to eliminate the chances of unwanted discharges.

Parts list for the ioniser

Resistors:
R1 ... R10 = 3M3

Capacitors:
C1 ... C27 = 33 n ... 47 n/630 V

Semiconductors:
D1 ... D27 = 1N4007 (1000 V)
F = 75 mA fuses

Hardware of the DOS Junior

In order to upgrade the Junior Computer to a DOS computer, certain hardware modifications are necessary. To allay any fears, let us point out that no tracks need be cut nor need any mechanical changes be made. All that is required is to solder an IC onto another one in piggyback fashion on the interface p.c.b. of the Junior Computer. In order to connect an EPSON dot matrix printer, an interface is required for the BUSY line. Since this interface only consists of three resistors, one transistor and a diode, it can easily be mounted in self-supporting fashion next to the V24/RS-232 connector.

G. de Cuyper

floppy-disk
interface
for the Junior

... and other 6502 computers, Part II

the Junior collects its stars and stripes

The second and last of these two articles describes the modifications that must be made to the hardware of the Junior Computer, to be able to run Ohio Scientific software on the Junior or any other 6502 computer. A new EPROM is required, to load software from the diskette during initialization (reset) of the computer. Documentation is available showing the source listing for the monitor program in the EPROM.

Let us take another look in the circuit diagram of the Junior interface p.c.b. (figure 1). NOR gate N33 is replaced by a NAND gate. Line 8K0 or EX is now no longer active in address range $0000 . . . 1FFF. The new address range with the NAND gate is E000 . . . FFFF. This addressing affects the memory chips of the Junior Computer as follows:
— 48 K bytes of dynamic RAM are located in adress range $0000 . . . BFFF. The advantage of dynamic RAM is that it is cheap and has a low current consumption. Three dynamic RAM cards (see Elektor, April 1982) are sufficient to provide the 48 K byte address range for the RAM.
— The address decoder on the standard Junior Computer p.c.b. (IC6) decodes address range $E000 . . . FFFF. The memory chips on the standard Junior Computer p.c.b. are therefore assigned

the following addresses:
EPROM IC2, type 2708:
$FC00 . . . FFFF
PIA, RAM, TIMER, type 6532:
$FA00 . . . FBFF (documentation)
RAM IC4 and IC5 type 2114:
$E000 . . . E3FF
The memory chips on the Junior interface p.c.b. have the following addresses:
VIA IC1, type 6522:
$F800 . . . F9FF (documentation)
RAM IC2 and IC3, type 2114:
$E400 . . . E7FF
EPROM IC4 and IC5, type 2716:
$E800 . . . F7FF

The second hardware modification concerns the interface for the BUSY line of the EPSON printer. Figure 2 shows how this interface is connected to the Junior. Relay Re1 is discharded. LED D4 becomes the BUSY indicator in this arrangement and operates in parallel with the BUSY lamp on the EPSON.
The drawings of figures 3 and 4 clarify the hardware modifications. After implementation of these modifications it is only necessary to plug the type 2708 (ESS 515) EPROM into the socket on the standard Junior Computer p.c.b. The two EPROMs IC4 and IC5 on the Junior interface p.c.b. (PM and TM) are no longer required, because the input/output programs for printer control are located in the 2708 EPROM. The address space assigned to IC4 and IC5 is now free for user programs. One more item that must not be forgotten is to fit a wire link between soldering points 'R' and 'S' on the Junior interface p.c.b. (WITH).
The Junior Computer has now been upgraded to a DOS computer. Plug at least two or three dynamic RAM cards into the bus card of the Junior Computer. The lines for address decoding on the RAM cards should be wired as follows:
RAM card 1:   U — 0
            V — 1
            X — 2
            Y — 3
RAM card 2:   U — 4
            V — 5
            X — 6
            Y — 7
RAM card 3:   U — 8
            V — 9
            X — A
            Y — B

At this stage, do not yet plug the floppy disk interface into the bus card of the Junior. Power-up the computer as usual and press the <RST> key on the hex keyboard. The display on the Junior should now light up. The command keys <AD>, <DA>, <+> and <GO> have the same significance as previously. Only the <PC> key has a new function. Once the disk operating system has been loaded into the computer, the DOS command interpreter can be called with the <PC> key. But we shall examine this in more detail later.
Table 1 shows the memory map of the DOS Junior Computer. This memory map also applies to all other 6502 com-

1

Figure 1. A part of the circuit diagram of the Junior Computer interface card. Gates N33 and N34 are replaced by a 74LS10 NAND gate. This results in a new memory area for the memories on the standard Junior Computer and on the interface card.

puters that are connected to the floppy disk interface. Adresses C000...FBFF can vary from one computer to another. The only important detail is that the computer must be able to address at least 32 K bytes of contiguous RAM in the lower address range. If, on a computer other than the Junior, the address range FC00...FFFF should already be assigned, the bootstrap software should be relocated to another memory area. This should be relatively simple using the documentation.

Software of the DOS Junior

The software of the DOS Junior Computer is oriented on the latest standards in computer design. This means that the computer is provided with a minimum of ROM intelligence and as much RAM as possible. The advantages of this computer system become clear:

Since the system software, whether BASIC, FORTH, Assembler or a word processor, has to be loaded rapidly from the diskette into the computer, not much space is wasted for the ROM address range. The ROM contains only sufficient intelligence to allow the computer to operate the hex display and keyboard and transmit/receive to and from the Elekterminal. Another function of the ROM intelligence of the Junior is to load track 0 from the diskette into the Junior Computer.

Thus BASIC, Assembler etc. are no longer stored in the ROM but are loaded from the diskette into the computer. This is referred to as 'portable software'. The decisive advantage of portable software is that it can be easily modified. Previously, when software errors were detected or when the system was to be updated, it was necessary to plug a new

set of EPROMs into the computer; now with portable software we only need to mount a new diskette on the drive. It is therefore easy to eliminate software errors and the system can be upgraded in keeping with the latest state of the art without difficulty. We make full use of these advantages with the DOS Junior Computer.

Let us examine Table 1 once again. Page 0 and the system stack are located in address range $0000...01FF. Address space $0200...22FF is intended for the 'transient processor'. What is a transient processor? This is the software that makes the computer system operable. If, for example, you are working in BASIC, the transient processor is the BASIC interpreter. If you are working in machine language, then Assembler or Ohio Scientific's Extended Monitor is the transient processor.

The system software for controlling the floppy disk drive and the printer, as well as a memory-mapped video display unit takes up about 4 K bytes of RAM. With OS-65D V3.1 the DOS software occupies memory area $2300...3278. The work space or memory area in which the programmer's own program is stored begins at address $327E ...When you type a BASIC program into the computer it is stored from address $327E ... onwards. The data are written into the floppy disk drive from this address onwards. Data which are read from the diskette into the computer are also stored from this address onwards. With OS-65D V3.3 the work space begins at address $3A7E. The first five bytes of the work space are known as the header. These five bytes contain the following information:

1) Start address on the file (2 bytes)
2) End address on the file (2 bytes)

Table 1. The new memory map for the DOS Junior Computer. On account of these extensions the workspace is reduced by 4 K bytes with the OS-65D V3.3. The transient processor overwrites address range $2200...22FF of the DOS software.

Memory map
BOOTSTRAP RES, IRQ, NMI
6532: RAM, TIMER, PIA
6522: VIA
IC5 Interface Board (2716)
IC4 Interface Board (2716)
2k Static RAM
Memory Mapped VDU
not used
Floppy I/O
Work Space
System Software DOS
Transient Processor
System Stack, Page Zero

2

Figure 2. This is how the interface is connected to PB6 for the EPSON printer. If PB6 is a logic 1, the send output (RS-232 connector pin 3) of the computer is inhibited. If no printer is connected, resistor RI1 ensures that the send output is enabled.

3

Figure 3. This hardware modification provides the Junior Computer with a new memory arrangement. The drawing shows the 'piggy-back' installation of the ICs.

3) Length of the file in pages (1 byte; 1 page = 256 bytes)

Next to the work space is the 4 K byte page $DXXX. The memory-mapped video display unit of Ohio Scientific is located in this address range. A video unit of this type differs from the Elekterminal in that the computer can transport data to the monitor screen directly via the data bus. The data interchange between the screen and the computer is much more rapid with the memory-mapped video display unit (VDU) than with a video interface using the V24/RS-232 interface.

2 K bytes of static RAM are located in address range $E000...E7FF. This RAM was previously located in the range $0000...07FF. In future we shall use this RAM area for the object code that is generated by the Assembler. You can now assemble a source file with the Assembler, print a listing if desired and instruct the computer to execute directly the machine code generated by the Assembler. Please consult Ohio Scientific's Assembler Manual for further details.

Adress range $E800...FFFF to IC4 and IC5 on the interface card of the Junior and to the two interface chips 6522/6532 and the 2708 bootstrap EPROM. The two EPROMs IC4 and IC5 on the interface card of the Junior are now freely accessible to the programmer. Personal software or programs which one does not wish to load from the floppy disk into the computer can be loaded into the two EPROMs (2716) for long term applications.

The bootstrap EPROM (ESS515)

The bootstrap EPROM is addressed in the range $FC00...FFFF. It contains only 1 K byte of software. The software in the bootstrap EPROM can be subdivided into eight groups:

1) Hex display monitor. This program is very similar to the original monitor of the Junior. The commands <AD>, <DA>, <GO>, <+> have kept their significance. Only the <PC> key has a different function. The DOS command interpreter can be called directly from the hex keyboard with the <PC> key. The main purpose of the hex display monitor is to be able to modify the software on the Ohio Scientific diskettes. This allows Ohio software to be converted to Junior software.

Important start addresses can be called with the hex display monitor and started with the <GO> key.
 – RESBAS * $FF17
 – RESDOS * $FF34
 – VONE * $FFE2
 – VTHREE * $FFE8

2) Loading the BASIC interpreter from the diskette. You can load BASIC from the diskette into the Junior Computer with the command <AD> FF17 <GO> (RUBOUT). To distinguish between command keys on the hex keyboard and Elekterminal keys, we shall

4
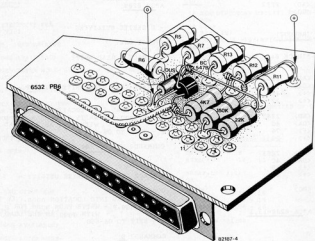
Figure 4. The EPSON interface is placed on the interface card of the Junior Computer as shown here.

write the command keys of the hex keyboard between <> symbols and command keys on the Elekterminal between () brackets in future.

Once BASIC is loaded and the computer has responded on the terminal the transient processor is ready for program interrupts. During output, you can interrupt a BASIC program with the (BREAK) key on the terminal. If the (BREAK) key was pressed during a LIST command, the BASIC interpreter prints 'Break'. If you have started a BASIC program with the RUN command and wish to stop output of the program, simply press the (BREAK) key. The BASIC interpreter responds with 'BREAK IN LINE X'. All program variables and pointers are then saved in the stack. You can restart the program after the interrupt with the CONT statement. The indirect jump vector for the (BREAK) key is automatically set by the computer via address $FF17 when the BASIC program is started. The break vector is stored in address $FA7C and $FA7D.

3) Loading of DOS software from the diskette. In future you can load ELEKTOR's own software into your Junior Computer with the command <AD> FF34 <GO> (RUBOUT). The address DOS is intended for future expansions and 'non-Ohio-software'.

4) Adapting an OS-65D V3.1 Ohio diskette.
An OS-65D V3.1 Ohio Scientific diskette can be adapted to your Junior Computer with the command <AD> FFE2 <GO> (RUBOUT). When the monitor is started at the address VONE * $FFE2 the following occurs:

— The computer positions the read/write head of the drive on track D.

— The computer reads the data on track 0 and stores these data at address $2200 . . . in the memory.

— The computer positions the read/write head of the drive on track 1.

— The computer reads the data on track 1 and stores these data at address $2A00 . . . in the memory. The entire disk operating system is now loaded in the computer and can be modified by the programmer with the hex keyboard.

— Once track 0 and track 1 have been loaded into the computer a jump is made to the hex display monitor

and the computer responds with "Track 0&1" on the printer.

5) Adapting an OS-65D V3.3 Ohio tutorial disk 5.
An OS-65D V3.3 Ohio Scientific tutorial disk 5 can be adapted to your Junior Computer with the command <AD> FFE8 <GO> (RUBOUT). For track 1 and track 1 the same applies as under 4). However, once track 0 and track 1 have been loaded into the computer the following occurs:

— The computer moves the read/write head of the drive to track 6. The data on track 6, sector 2 are read into the memory from address $3200 . . . onwards. Sector 2 is one page long.

— The data on track 6, sector 3 are read into the memory from address $0000 . . . onwards. Sector 3 is one page long.

— The computer removes the read/write head of the drive to track 13. The data on track 13, sector 1 are loaded into the computer from address $3A79 . . . onwards. Sector 1 of track 13 is eight pages long. When all tracks have been loaded into the computer the message "Track 0&1" is issued, as with OS-65D V3.1, and a jump is made to the hex display monitor.

6) The <PC> key
You can leave the hex display monitor and jump to the DOS command interpreter with the <PC> key. Printer I/O is initialized but no new baud rate measurement is made. The computer responds with the prompt A* or B*, etc..

7) Printer input routine.
The printer input routine receives a character from the terminal. The received ASCII character is in the accumulator of the CPU after the return from the input subroutine. Bit 7 of the character is always a logic zero. The contents of the index registers are not affected

5

Transfer of Control Commands
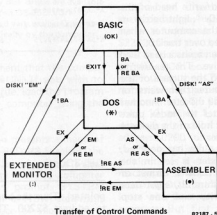
Figure 5. The command transfer to the different transient processors: from BASIC to ASSEMBLER, from ASSEMBLER to EXTEND MONITOR, etc. and vice versa. The 'control centre' is the DOS. It allows the BASIC, ASSEMBLER and EXTENDED MONITOR transient processors to be loaded from the diskette into the computer.

by calling this subroutine. The start address of the printer input routine is: RECCHA* $FE1B (call: JSR RECCHA).
8) Printer output routine.

The printer output routine sends the character in the accumulator of the CPU to the terminal. The transfer format is:
— one start bit
— seven data bits
— no parity bit
— two stop bits
The contents of the index registers are not affected by calling this subroutine. The start address of the printer output routine is:
PRCHA* $FEA3 (call: JSR PRCHA).

How does the bootstrap routine operate?

Now that we know what the software in the bootstrap EPROM consists of, we should discuss operation of the bootstrap routine. Once you have entered
<RST>
<AD> FF17
<GO>
into the computer, the following operations take place:
1) The computer sets the indirect jump vector for the (BREAK) key on the terminal. The NMI vector points to the hex display monitor.
2) The computer initializes the I/O on the floppy disk interface p.c.b. (6821 and 6850) and the serial I/O for the terminal (6532). When all I/O lines have been initialized the computer waits for the RUBOUT character from the terminal, to measure the baud rate. The baud rate is stored in memory cells $FA5A...FA5D (see floppy disk documentation).
3) Once the baud rate of the terminal has been measured, the computer loads track 0 (= 2 K bytes of software in machine language). The steps required to load track 0 into the computer are as follows:
— Position the read/write head of the drive over track 0. A light barrier in the drive covers the opening in the computer when the head is positioned over track 0.
— The computer then emits a head load pulse to the drive. The read/write head is lowered onto the surface of the diskette. The computer then waits for the index hole in the diskette. Another light barrier generates the index pulse as soon as the index hole of the diskette passes the light barrier.
— Once the index pulse has decayed, the control register is set in the ACIA (6850). The transfer format of the ACIA is: one start bit, eight data bits, one even parity and one stop bit.
— The computer reads the first byte from the diskette. This byte is the most significant start address of the memory area in which track 0 is stored (= $22). The second byte from the diskette is the least significant byte of the start address (= $00). Both bytes are loaded into the bump pointer (load

```
<RST>
<AD>     FFE2
<GO>

(RUBOUT)

*TRACK 0#1*

<AD>     2217
<DA>     4C
<+>      40
<+>      22
<AD>     2225
<DA>     4C
<+>      76
<+>      22
<AD>     2283
<DA>     4C
<+>      A6
<+>      22

<PC>

A*CA 0200=13,1
```

Table 2. Adapting an OS-65D V3.1 diskette to the Junior Computer (Part 1), if only one drive is available.

```
A*IN
ARE YOU SURE?Y
A*GO 0200

- DISKETTE UTILITIES -

SELECT ONE:
1) COPIER
2) TRACK 0 READ/WRITE
? 2

- TRACK ZERO READ/WRITE UTILITY -

COMMANDS:
Rnnnn — READ INTO LOCATION nnnn.
Wnnnn/gggg,p — WRITE FROM p PAGES
                WITH gggg AS THE LOAD VECTOR
E — EXIT TO OS-65D

COMMAND? W2200/2200,8

- TRACK ZERO READ/WRITE UTILITY -

COMMANDS:
Rnnnn — READ INTO LOCATION nnnn.
Wnnnn/gggg,p — WRITE FROM nnnn FOR p PAGES
                WITH gggg AS THE LOAD VECTOR
E — EXIT TO OS-65D

COMMAND? E

A*HOME
A*CA 01,1=2A00/8
```

Table 3. Adapting an OS-65D V3.1 diskette to the Junior Computer (Part 2).

```
A*CA 4000=02,1   A*CA 4000=10,1   A*CA 4000=18,1   A*CA 4000=26,1
A*CA 4800=11,1   A*CA 4800=11,1   A*CA 4800=19,1   A*CA 4800=27,1
A*CA 5000=24,1   A*CA 5000=12,1   A*CA 5000=20,1   A*CA 5000=28,1
A*CA 5800=15,1   A*CA 5800=13,1   A*CA 5800=21,1   A*CA 5800=29,1
A*CA 6000=06,1   A*CA 6000=13,1   A*CA 6000=22,1   A*CA 6000=30,1
A*CA 6800=07,1   A*CA 6800=12,1   A*CA 6800=23,1   A*CA 6800=31,1
A*CA 7000=09,1   A*CA 7000=13,1   A*CA 7000=24,1   A*CA 7000=32,1
A*CA 7800=09,1   A*CA 7800=14,1   A*CA 7800=25,1

                 A*CA 6800=15,1
A*SA 01,1=4800/8 A*SA 10,1=7000/16,1  A*SA 18,1=4000/8  A*SA 26,1=4000/8
A*SA 03,1=5800/8 A*SA 11,1=7800/17,1  A*SA 19,1=4800/8  A*SA 27,1=4800/8
A*SA 05,1=5000/8 A*SA 10,1=5000/8     A*SA 20,1=5000/8  A*SA 28,1=5000/8
A*SA 06,1=6000/1 A*SA 11,1=4800/8     A*SA 21,1=5800/8  A*SA 29,1=5800/8
A*SA 07,1=6400/8 A*SA 12,1=5000/1     A*SA 22,1=6000/8  A*SA 30,1=6000/8
A*SA 09,1=7800/8 A*SA 12,3=5200/1     A*SA 23,1=6800/8  A*SA 31,1=6800/8
                 A*SA 12,4=5300/1     A*SA 24,1=7000/8  A*SA 32,1=7800/8
                 A*SA 13,1=4800/8     A*SA 25,1=7800/8  A*
                 A*SA 13,1=5800/5
                 A*SA 14,1=6800/8                       <RST>
                 A*SA 15,1=6800/8                       <AD>  FF17
                 A*SA 16,1=7800/8                       <GO>
                 A*SA 17,1=7800/8                       (RUBOUT)

                                      OS-65D V3.0
                                      OSI 9 DIGIT BASIC
                                      COPYRIGHT 1977 BY MICROSOFT
                                      36215 BYTES FREE

                                      OK
```

Table 4. Adapting an OS-65D V3.1 diskette to the Junior Computer (Part 3).

pointer). Thus the bump pointer points to address $2200. The computer then reads the third byte from the diskette. This byte indicates the number of pages on track 0 (= $08).
— The next bytes are 2 K bytes of software in machine language. These bytes are loaded from the diskette into the computer. The memory area is $2200...29FF. So track 0 has been stored in the memory, the read/write head is raised from the surface of the diskette and a jump to address $2200 takes place. Starting with this address, the computer finds further instructions concerning the address into which the tracks and sectors are to be loaded. Normally the two K bytes of software on track 1 are loaded into address range

```
RUN'BEXEC*'

BASIC EXECUTIVE FOR
OS-65D V3.1

JUNE 25, 1980 RELEASE

FUNCTIONS AVAILABLE:

   CHANGE- ALTER WORK-
      SPACE LIMITS

   DIR- PRINT DIRECTORY

   UNLOCK- UNLOCK SYSTEM
      FOR END USER MODI-
      FICATIONS

FUNCTION? UNLOCK

SYSTEM OPEN

OK
RUN

BASIC EXECUTIVE FOR
OS-65D V3.1

JUNE 25, 1980 RELEASE

FUNCTIONS AVAILABLE:

   CHANGE- ALTER WORK-
      SPACE LIMITS

   DIR- PRINT DIRECTORY

   UNLOCK- UNLOCK SYSTEM
      FOR END USER MODI-
      FICATIONS

FUNCTION? DIR
LIST ON LPRINTER INSTEAD OF DEVICE # 1 ? NO

OS-65D VERSION 3.0
-- DIRECTORY --

FILE NAME    TRACK RANGE

OS65D3       0 - 12
BEXEC*      14 - 14
CHANGE      15 - 16
CREATE      17 - 19
DELETE      20 - 20
DIR         21 - 21
DIRSORT     22 - 23
RANLST      23 - 24
RANDEL      25 - 26
SECDIR      26 - 28
SEQLST      27 - 28
TRACE       29 - 29
ZERO        30 - 31
ASAMPL      32 - 32

  50 ENTRIES FREE OUT OF 64

OK
```

Table 5. 'Trial run' of an adapted OS-65D V3.1 diskette. Utility program BEXEC* is called when the BASIC interpreter has been loaded.

$2A00 ... 31FF. Track 0 and track 1 jointly contain 4 K bytes of software in machine language, which make the entire disk operating system operable.
— Once the disk operating system (DOS) has been loaded into the computer, the BASIC interpreter is loaded from the diskette into the memory. With OS-65D V3.1 the BASIC interpreter is located on tracks 2 . . . 4. With OS-65D V3.3 the BASIC interpreter and various extensions of the editor are located on tracks 2 . . . 4, track 6 and track 13. When the interpreter has been loaded a jump is made to the cold-start entry of the BASIC interpreter ($20E4). The system then responds with the prompt OK.
— The system is not yet ready for the statements LIST, CONT etc.. Even a BASIC file cannot yet be created. The

```
OK
LIST

   10 REM DIRECTORY UTILITY FOR OS-65D VERSION 3.0
   20 REM
   30 NF=m
   40 PN=1897
   50 DEF FNA(X)=10*INT(X/16)+X-16*INT(X/16)
BREAK
OK

NEW
OK
RUN'DIR'
LIST ON LPRINTER INSTEAD OF DEVICE # 1 ? NO

OS-65D VERSION 3.0
-- DIRECTORY --

FILE NAME    TRACK RANGE

OS65D3       0 - 12
BEXEC*      14 - 14
OK
CONT
CHANGE      15 - 16
CREATE      17 - 19
DELETE      20 - 20
DIR         21 - 21
BREAK IN 11100
OK
```

Table 6. Checking the (BREAK) key with the LIST command and the RUN statement.

only BASIC statement that the computer recognizes is RUN. If you wish to generate a BASIC file, load the program BEXEC* into the computer using the command:
RUN 'BEXEC*'
The computer then presents a menu of options. With OS-65D V3.1 select the option 'UNLOCK' and with OS-65D V3.3 select option '9'. The computer responds with the prompt 'SYSTEM OPEN'. Now enter a 'NEW' statement and the work space of the Junior is formatted for your BASIC file.

The DOS and its capabilities

The DOS can easily be converted to various transient processors with Ohio's disk operating system, which is located on track 0 and track 1

```
                                                 #2
                                                 #3
                                                 #4
                                                 #5
                                                 #6
                                                 #7
A*CA 0200=13,1                                   #8
                                                 #9
A*GO 0200                                         10
                                                 11
                                                 12
- DISKETTE UTILITIES -                            13
                                                 14
SELECT ONE:                                       15
1) COPIER                                         16
2) TRACK 0 READ/WRITE                             17
? 1                                               18
                                                 19
- DISKETTE COPIER -                               20
                                                 21
FROM DRIVE (A/B/C/D)? A                           22
                                                 23
TO DRIVE (A/B/C/D)? B                             24
                                                 25
                                                 26
STARTING TRACK? 2                                 27
                                                 28
ENDING TRACK (INCLUSIVE)? 12                      29
                                                 30
READY (Y/N)? Y                                    31
                                                 32
```

Table 7. If two floppy disk drives are available (drive A and drive B), an OS-65D V3.1 diskette can be adapted very easily. Copying is performed automatically by the computer.

of the diskette. Figure 5 shows how the individual connections between the DOS and the processors can be made and cancelled. If, for example, you start the DOS at address $FF17 the Junior becomes a BASIC computer. If you want to convert the Junior to an Assembler computer, you must enter EXIT in order to leave the BASIC interpreter. After the EXIT command the Junior responds with the DOS prompt A* or B*, etc. on the printer. If you then enter AS or Assembler the Junior converts itself to an Assembler Computer. You can then create an Assembler file and write on the diskette with the DOS. However, you can also assemble the source file and program the object code directly in the EPROM with the ELEKTOR EPROM programmer, without having to type in a single byte. The computer performs this task automatically. For further details regarding operation with Assembler, please consult Ohio Scientific's Assmbler Manual. Note that the Assembler and Extended Monitor are not on the diskette in the case of OS-65D V3.1. Only OS-65D V3.3 has the Assembler and Extended Monitor (EM) on the diskette as standard.

Adapting an OS-65D V3.1 diskette for one drive

If you have only one drive, V3.1 can only be adapted to the Junior Computer with a considerable amount of typing. Tables 2, 3 and 4 show how this is done. First the start the system with the hex keyboard. A program with which a V3.1 diskette can be loaded into the Junior Computer to facilitate modification begins at address $FFE2. When the (RUBOUT) key has been pressed the computer loads track 0 and track 1 into the memory, and responds with "TRACK 0&1". The display lights up, the vectors for the input and output routines are automatically loaded and the programmer can now modify some bytes at addresses $2217, $2245 and $2283. Once the bytes have been modified in accordance with Table 2, a jump to the DOS command interpreter is made using the <PC> key. The DOS responds with the prompt A*.
The command CA 0200=13,1 loads from track 13, sector 1 of the diskette. The data are stored in the computer from address 0200 onwards. The program that we have just loaded into the Junior Computer is a disk copier and track 0 read/write utility. You can write the modified DOS onto track 0 of your diskette with the track 0 read/write utility program. But first you must initialize your diskette. Remove the Ohio diskette from the drive and insert your diskette, then close the door of the drive. Table 3 shows the next steps: type the word in 10. This command initializes the diskette. The system asks: 'ARE YOU SURE? '. Your reply is Y(ES). The drive ceases clicking when the formatting in-

Table 8. Adapting an OS-65D V3.3 diskette.
BASIC is loaded via a jump to the DOS
command interpreter (GO 2276) and copied
with the utility program BEXEC*. Finally
a 'trial run' is executed to ensure that the
diskette was adapted correctly.

```
<RST>
<AD>   FFE8
<GO>

(RUBOUT)

*TRACK 0&1*

<AD>   2217
<DA>   4C
<+>    40
<+>    22

<AD>   2245
<DA>   4C
<+>    76
<+>    22

<AD>   2285
<DA>   8E
<+>    C6
<+>    2A
<+>    4C
<+>    B3
<+>    22

<AD>   2E84
<DA>   4C
<+>    98
<+>    2E

<PC>

A*CA 0200=06,4

A*GO 0200

 - TRACK ZERO READ/WRITE UTILITY -

COMMANDS:
Rnnnn - READ INTO LOCATION nnnn.
Wnnnn/gggg,p - WRITE FROM nnnn FOR p PAGES
                    WITH gggg AS TRE LOAD VECTOR
E - EXIT TO OS-65D

COMMAND? W2200/2200,8

 - TRACK ZERO READ/WRITE UTILITY -

COMMANDS:
Rnnnn - READ INTO LOCATION nnnn.
Wnnnn/gggg,p - WRITE FROM nnnn FOR p PAGES
                    WITH gggg AS TRE LOAD VECTOR
E - EXIT TO OS-65D

COMMAND? E

A*SA 01,1=2A00/8

A*

<RST>
<AD>   FF17
<GO>

(RUBOUT)

OS-65D V3.0
OSI 9 DIGIT BASIC
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34177 BYTES FREE

Ok
RUN"BEXEC**

OS-65D  Tutorial disk five - Sept. 16, 1981
        1 > Directory
        2 > Create a new file
        3 > Change a file name
        4 > Delete file from diskette
        5 > Create blank data diskette
        6 > Create data diskette with files
        7 > Create buffer space for data files
        8 > Single or dual disk drive copier
        9 > Enter OS-65D system
Type the number of your selection
and depress RETURN ? 1

        Directory utility
Directory of which drive ?
Type A,B,C or D and depress RETURN <A> ?

Do you want to list the directory
to the printer (Yes or No) <No> ?

  -- Directory --
File name  Track range
--------   -----------
  OS65D3      0 - 13
  BEXEC*     14 - 16
  COPIER     17 - 18
  CHANGE     19 - 20
  CREATE     21 - 22
  DELETE     23 - 23
  DIR        24 - 24
  RANLST     25 - 26
  RENAME     27 - 27
  SECDIR     28 - 28
  SEQLST     29 - 30
  TRACE      31 - 31
  ZERO       32 - 33
  ASAMPL     34 - 34
```

```
ATWENB       35 - 35
COLORS       36 - 36
MODEM        37 - 38
COMPAR       39 - 39
 46 Entries free out of 64

Depress RETURN to continue ?
<RST>
<AD>   FFE8
<GO>

(RUBOUT)

*TRACK 0&1*

<PC>

A*GO 2276

OS-65D V3.0
OSI 9 DIGIT BASIC
COPYRIGHT 1977 BY MICROSOFT
33921 BYTES FREE

Ok
RUN"BEXEC**

OS-65D  Tutorial disk five - Sept. 16, 1981
        1 > Directory
        2 > Create a new file
        3 > Change a file name
        4 > Delete file from diskette
        5 > Create blank data diskette
        6 > Create data diskette with files
        7 > Create buffer space for data files
        8 > Single or dual disk drive copier
        9 > Enter OS-65D system
Type the number of your selection
and depress RETURN ? 8

 - Diskette copier -

Copy from which drive (A/B/C/D) ? A

Copy to which drive (A/B/C/D) ? A

What is the last track to be copied (Inclusive) <0-39> ? 39

Are you ready to start copying (Y/N) ? Y

Insert master diskette -- press <RETURN> ?

Reading --

Insert blank diskette -- press <RETURN> ?

Initializing --
        Track 01 - 01/08
        Track 02 - 01/08
        Track 03 - 01/08
        Track 04 - 01/08
        Track 05 - 01/08
        Track 06 - 01/01 - 02/01 - 03/01 - 04/02
        Track 07 - 01/08
        Track 08 - 01/08
        Track 09 - 01/08
        Track 10 - 01/08
        Track 11 - 01/01 - 02/01 - 03/01 - 04/01 - 05/01 - 06/01 - 07/01
        Track 12 - 01/01 - 02/01 - 03/01 - 04/08
        Track 13 - 01/08
        Track 14 - 01/08

Insert master diskette -- press <RETURN> ?

Reading --

Insert blank diskette -- press <RETURN> ?

        Track 15 - 01/08
        Track 16 - 01/08
        Track 17 - 01/08
        Track 18 - 01/08
        Track 19 - 01/08
        Track 20 - 01/08
        Track 21 - 01/08
        Track 22 - 01/08
        Track 23 - 01/08
        Track 24 - 01/08
        Track 25 - 01/08
        Track 26 - 01/08
        Track 27 - 01/08
        Track 28 - 01/08

Insert master diskette -- press <RETURN> ?

Reading --

Insert blank diskette -- press <RETURN> ?

        Track 29 - 01/08
        Track 30 - 01/08
        Track 31 - 01/08
        Track 32 - 01/08
        Track 33 - 01/08
        Track 34 - 01/08
        Track 35 - 01/08
        Track 36 - 01/08
        Track 37 - 01/08
        Track 38 - 01/08
        Track 39 - 01/05 - 02/02
```

6
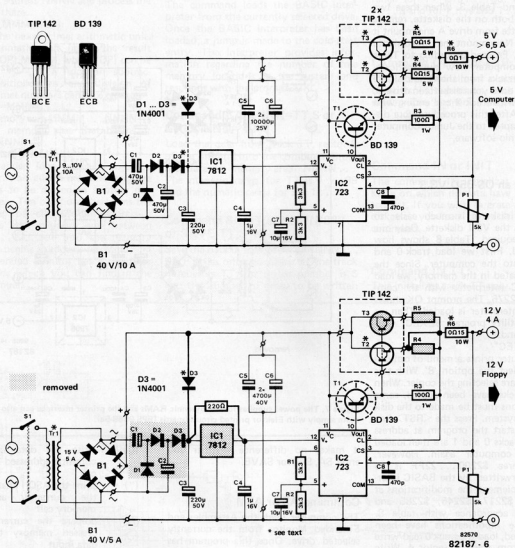
Figure 6. These two hefty power supplies are more than adequate for powering the DOS Junior Computer. They can both be constructed on Elektor printed circuit boards (EPS 82570). They are sufficiently rated to power a complete Junior Computer, including four disk drives.

formation has been written on all 39 tracks of the diskette. After initialization the diskette is ready for read/write operations. Now proceed according to Table 3. First you write eight pages of software on track 0 with the command W2200/2200,8. The start address is $2200 and the load vector for the bootstrap function is also $2200. The first half of the DOS is thus written on the diskette.

The command SA 01,1=2A00/8 saves a data block of a length of eight pages on track 1, sector 1, beginning with start address $2A00. You save the second part of the DOS on the diskette with this command. Since, with the V3.1 copier it is not possible to copy from drive A to drive A, copying must be performed track by track and manually. Table 4 shows how this is done. It

should be noted that with the 'CA' commands the Ohio diskette is mounted in drive A, whilst with the 'SA' commands your diskette is mounted in drive A. When tracks 2 ... 32 have been copied from the Ohio diskette onto your diskette, a trial run can be started. Switch off the supply voltage of the computer. Wait a few seconds and switch the supply voltage on again. Mount your diskette in drive A. Start the bootstrap function at address $FF17 as shown in Table 4. The system responds with a message and the prompt 'OK'. The number of free bytes depends on the capacity of the RAM. With a 48 K byte dynamic RAM you have access to 36225 memory locations.

Start the utility program 'BEXEC*' with the command RUN 'BEXEC*'. This program is written in BASIC. The com-

puter prints a menu of options. First select the option UNLOCK; the computer is now ready for all BASIC statements.

Proceed as shown in Table 5. Start the directory utility program. The computer then prints the entire directory. Finally, a check should be made to establish whether the (BREAK) function is functioning correctly. Table 6 shows how a LIST command is first interrupted and a program is then terminated with the (BREAK) key. You can continue the program from its point of interruption using the CONT command.

Adapting an OS-65D V3.1 diskette for two drives

It is considerably easier to adapt V3.1 to the Junior Computer when two

drives are connected. Modify and copy track 0 and track 1 in accordance with Table 2 and Table 3. When these two tracks are both on the diskette, remove your diskette from drive A and mount it in drive B. Now mount the Ohio diskette in drive A. Proceed according to Table 7. The computer now automatically copies all tracks from the Ohio diskette in drive A onto your diskette in drive B, beginning with track 2 and ending with track 32. After this procedure your diskette is adapted to the Junior Computer with the Ohio software.

Adapting an OS-65D V3.3 diskette

The V3.3 diskette is much easier to adapt than the V3.1 diskette. Only one drive is required. Table 8 shows how to proceed. First we load track 0 and track 1 into the computer. Since the DOS is located in the memory, we load the BASIC interpreter with the command GO 2276. The prompt OK shows that the interpreter is loaded. Then we load the utility program BEXEC* with the command:
RUN 'BEXEC*'
The computer prints a menu of options and we select the option '8'. With this option we are selecting the copier. When all the tracks have been copied, some modifications must be made to the disk operating system. Press the <RST> key again and start the program at address $FFE8. Tracks 0 and 1 are then loaded into the computer again. However, memory area $2200 . . . 22FF is no longer overwritten by the BASIC interpreter. Implement the modifications at addresses $2217, $2245, $2285 and $2E84 in accordance with table 8. Once these modifications have been implemented, load the track 0 read/write program from track 6, sector 4. Write the modified DOS onto track 0 of the diskette again using this program. The command SA 01,1=2A00/8 saves eight pages of DOS software on track 1. You now have a V3.3 diskette which is adapted to the Junior Computer. You can start BASIC at address $FF17. The DOS and BASIC interpreter are automatically loaded into the Junior Computer after you have pressed the (RUBOUT) key — see Table 8.

The DOS command interpreter

As already mentioned, the disk operating system has its own command interpreter. We shall now examine the most important commands. If a command is not entered correctly an error message is issued.
Whenever the computer has printed the DOS prompt A* or B* you can enter a DOS command after the prompt. The computer only recognizes the first two upper-case letters of each command. With a SAVE command, for example,

removed
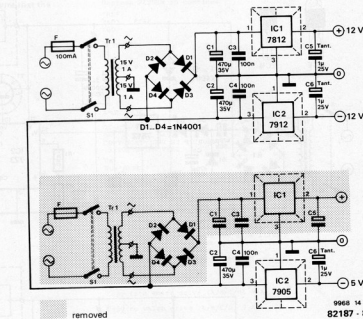
Figure 7. The power supplies for the dynamic RAMs and the printer interface can also be built quite simply with Elektor printed circuit boards (EPS 9968-5a).

it makes no difference whether you enter SA, SAV or SAVE.

Command AS or ASM

The computer loads the Assembler and Extended Monitor from the currently selected drive. Once this program has been loaded in machine language, a jump is made to the cold-start entry of the Assembler. The Assembler is then called with a line-oriented editor.

Command EM

The computer loads the Assembler and Extended Monitor from the currently selected drive. Once this program has been loaded in machine language, a jump is made to the Extended Monitor. This is a program with which a machine language program can easily be checked. The Extended Monitor has its own command interpreter. The most important commands are:
!STRING
Send 'STRING' to the DOS command interpreter as a command.
aNNNN
Open the memory cell with the address NNNN for execution of the following subcommands:
(LF) open the next memory cell
(CR) close the currently addressed memory cell

(D)(D) write the data into the currentlt addressed memory cell
('') print the ASCII character of the currently addressed memory cell
(/) prepare the currently addressed memory cell for data input
(^) open the previously addressed memory cell for data input

BN,LLLL
Set the break point with number N at address LLLL. The numeric range of the break point number N is 1 . . . 8.
EN
Eliminate the break point with number N.
A
Print the accumulator contents resulting from the last break point.
C
Start the program after the last break point.
DNNNN,MMMM
Make a memory dump from address NNNN up to and excluding address MMMM.
EX
Leave the Extended Monitor and return to DOS.
FNNNN,MMMM=DD
Fill the memory area beginning with address MMMM and ending with address MMMM—1 with the data DD.

GNNNN
Jump to address NNNN and process the program there.

HNNNN,MMMM(OP)
Call of the hexadecimal arithmetic unit. The arithmetic unit prints the result NNNN (OP) MMMM, where (OP) can be equal to +, −, *, /. Addition, subtraction, multiplication and division of hexadecimal numbers can be executed.

MNNNN=MMMM,LLLL
Move memory area MMMM . . . NNNN−1 into the memory area that begins at address NNNN.

RMMMM=NNNN,LLLL
The Extended Monitor has a so-called relocator. This allows machine language programs to be moved to another memory area. The computer performs the correcting of all absolute addresses: 'Relocate' the memory area between NNNN . . . LLLL−1 into the memory area that begins at address MMMM.

The Extended Monitor has some other commands which you can find in the Ohio Manual.

Command BA

The command loads the BASIC interpreter from the currently selected drive. Once the BASIC interpreter has been loaded, a jump is made to the cold-start entry. The interpreter provides information regarding the number of free memory locations in the system and responds with the prompt 'OK'.

Command CA NNNN=TT,S or CALL NNN= TT,S

Load the data from track TT, sector S of the diskette into the computer. Store the data in memory area NNNN . . . The numeric range for TT is 1 . . . 39 and the numeric range for S is 1 . . . 8.

Command SA TT,S=NNNN/8PP or SAVE TT,S=NNNN/P

Save the data in memory area NNNN . . . for P pages onto the diskette. The track number is TT, the sector number is S and the number of pages to be written

onto the diskette is P. The numeric range for TT is 01 . . . 39, for S it is 1 . . . 8 and for P it is also 1 . . . 8.

Command DI TT or DIR TT

This command allows a check of the numbers of sectors on track TT to be made. The numeric range of TT is 01 . . . 39.

Command IN or INIT

The command IN initializes a new diskette on which no data have been written yet. If you wish to erase a recorded diskette, you can do so with the IN command.

Command IN TT:

This initializes track TT only.

8

82187 - 11

82187 - 10

Figure 8. These modifications constribute greatly to the proper functioning of the dynamic RAM card.

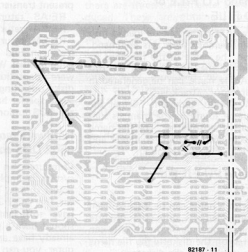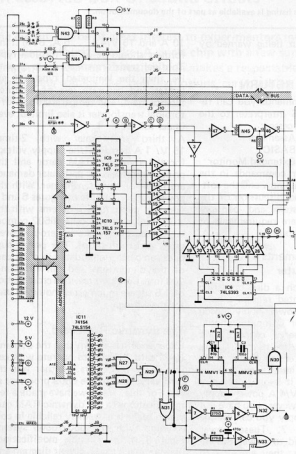|	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
FC00:	A9	1E	8D	83	FA	A9	01	85	FD	A2	FF	9A	78	D8	20	7C
FC10:	FC	20	C9	FD	A9	0F	85	FA	20	7C	FC	F4	F6	20	E1	F7
FC20:	C9	13	D0	07	A2	FF	9A	D8	6C	FA	20	98	8D	FA	20	02
FC30:	FD	85	FD	D0	14	C9	11	D0	A9	E7	A9	09	85	FD	4C	13
FC40:	12	D0	09	FA	D0	02	A9	FA	90	02	A2	00	FC	C9	14	D0	13
FC50:	FC	FD	FC	C9	15	D0	F2	85	9F	91	FA	C4	49	FC	A2	00	86
FC60:	0A	0A	0A	0A	85	FF	91	FA	4C	49	FC	A2	04	A9	26	26
FC70:	9F	91	FA	85	9F	CA	85	FF	FA	4C	49	FC	A9	D0	84	FA
FCA0:	FA	20	7F	FC	A5	F9	20	b8	FC	A9	20	9B	FC	20	02	FD
FCA0:	E6	8C	82	FA	09	80	49	F8	60	48	84	FC	4A	4A	4A	4A	20
FCC0:	CB	F6	68	29	0F	20	CB	FC	A4	FC	60	A8	A9	08	85	FA
FCD0:	60	A2	21	A1	00	20	A1	FC	20	91	FC	CA	D0	F5	18	75
FCF0:	60	A9	87	2C	A9	93	2C	A9	81	85	E8	A9	20	85	E9	60
FCF0:	60	8D	19	1A	60	FA	FA	A4	60	4D	79	29	13	19	13	19	13
FD10:	00	10	08	03	46	21	06	0E	20	1E	FD	6C	F0	00	20	4F
FD20:	FD	20	6F	FD	20	4F	FD	60	A4	A9	C8	A9	00	A2	44	8E	41
FD50:	00	C0	A9	04	8D	A2	08	A2	09	8C	18	8C	20	8D	4F	A9
FD70:	FD	00	00	A2	8D	8C	40	A9	03	20	4F	0E	18	8D	A2	58	8D
FD90:	18	28	DA	F3	FD	8D	5A	F5	DD	8C	8C	A9	03	28	58	8D
FDB0:	00	FA	86	F6	68	A8	18	C4	A8	8A	11	C4	8D	F8
FDC0:	FF	CA	D0	F6	68	28	18	60	A4	8A	A0	FA	FC	04
FDD0:	A2	FF	8E	5B	FA	EA	EA	A9	7F	8D	81	FA	4A	8D	FA	2C

FDF0:	03	8E	59	FA	2C	80	FA	30	FB	20	4F	FE	4E	5F	FA	6E
FE00:	5F	FA	2C	5E	FA	8D	0A	4D	5F	FA	8D	5D	FA	A2	08
FE10:	2D	72	FE	20	2E	FE	C9	7F	D0	85	60	20	FA	30	FB
FE20:	8E	61	FA	A2	08	28	72	FE	20	91	FE	2C	80	FA	10	F9
FE30:	38	6E	62	FA	CA	D0	F1	F0	07	18	60	82	FA	8D	5B	FA
FE50:	A5	FA	FA	69	80	5A	FA	8D	5A	FA	69	00	8D	5B	FA
FE60:	2C	80	FA	10	EA	A0	5A	FA	5E	FA	A5	5A	FA	38	FA	5B
FE80:	0C	AD	5A	FA	8D	5A	FA	AD	5B	FA	5B	FA	8D	5B	FA
FE90:	FA	B9	01	8D	5E	FA	AD	5F	FA	29	80	8D	5F	FA	AD	5E
FEA0:	8D	62	FA	29	FE	8D	82	FA	28	81	FA	A2	07	4E	62	FA
FEB0:	59	9A	AD	81	FA	29	01	8D	81	FA	28	01	FA	CA	D0
FEE0:	F2	2C	80	FA	10	A4	60	FA	6A	26	60	8C	A9	48	FA	03
FEF0:	A9	C1	8D	5C	FA	A9	2C	8D	5A	FA	A9	10	8D	5B	FA
FF00:	2C	51	2A	29	27	8D	80	FA	A9	08	8D	04	FA	A9	7F	8D
FF10:	81	FA	EE	5C	FA	A4	8D	4A	FA	8D	7C	FA	A9	28	8D	3C
FF20:	FA	A9	C8	8D	2B	FA	A9	F6	8D	2A	FA	8D	5E	26	20	0F
FF30:	2C	26	A9	2A	85	FF	20	54	27	F6	12	26	A9	2A	28	60
FF40:	D1	21	8D	22	23	8D	01	28	13	A3	A9	FE	8D	02	23
FF50:	8D	02	23	8D	12	23	A9	28	8D	04	FA	8D	26	A9	02	20
FF60:	2A	8D	26	85	FF	20	54	27	F6	C8	2E	26	A9	2A	85	FF
FF70:	21	23	8D	22	23	8D	01	23	A9	FE	8D	02	23
FF80:	FF	10	8D	28	23	8D	12	23	A9	28	8D	04	FA	8D	26	26
FFA0:	A9	29	85	FF	20	54	27	F6	12	2E	26	A9	2A	85	FF	26
FFB0:	29	8E	5C	9C	41	53	20	4C	4F	20	50	55	20	53	45
FFE0:	20	52	45	42	89	20	4F	4C	20	55	40	50	55	20	54
FFF0:	A2	FF	8E	5B	FA	EA	A9	7F	8D	81	FA	4A	8D	03	FA

Table 9. Hex dump listing for the bootstrap EPROM ESS515. The source listing is available as part of the documentation.

Command SE X or SELECT X

One of four drives can be selected with this command. The computer only operates with one selected drive. X = A, AB, C or D.

Command LO FILE or LOAD FILE

A file with a name can be loaded into the main memory with this command. However, the name of the file must be specified in the directory of the diskette. A file name can be generated in the directory (track 12) with the CREATE utility program. Further details can be found in the manuals supplied with the diskettes. The file name must begin with an alpha character and can be 1 . . . 6 characters long.

Command PU FILE or PUT FILE

A file with a name can be written from the main memory onto the diskette with this command. Before the file can be written on the diskette the file name must be specified in the directory.

Commands PU TT and LO TT

With this command a file in the work space of the computer can be written onto the diskette and read from the diskette into the computer without a file name. However, the file in the work space must not be longer than 2 K bytes. It is advisable not to use these two commands because it is easy to overwrite existing software on the diskette without being warned by an error message.

Command RE or RETURN

With RETURN commands you can return from the DOS interpreter to the present transient processor:

RE AS   return to Assembler
RE BA   return to BASIC
RE EM   return to Extended Monitor

You can find other commands in the Ohio Manual. We shall now end the software adaptation and discussion of disk operating system and consider some special hardware requirements of the DOS Junior Computer.

Hardware requirements of a 6502 DOS computer

Computers on which a disk operating system is implemented require a good power supply. The power supply chosen for the DOS Junior Computer should have sufficient reserve capacity and should have a pulse-free output. If you already have an extended Junior Computer, you can continue to use the existing power supply. It is only necessary to build a new 12 V/4 A power supply for the drive. If, however, you have not yet got a power supply you can use the circuits in figure 7. These power supplies are intended to power the entire DOS computer; they are easy to build and are reliable. The entire circuit can be accommodated on four ELEKTOR printed circuit boards: 2-times ESS 82570 and 2-times ESS 9968-5a. Two transformers are required with the following ratings: 9 . . . 10 V/

10 A and 15 V/4.4 . . . 5 A. Both transformers should be of the toroidal type. Toroidal transformers are more expensive than the laminated type but are lighter and generate less of an interference field. The temperature rise of a toroidal transformer is also limited, even under full load.

A third transformer with 2-times 15 V/1 A provides the supply voltage for the dynamic RAM cards and the printer interface. No particular demands are made of this transformer. With the power supply circuits of figures 6 and 7 you will never have problems with the DOS Junior or any other 6502 computer, because they are generously overrated and short-proof. The power supplies can be accommodated in a flat case of the dimensions 300 mm x 70 mm x 200 mm. Conductors with a cross-section of 1.5 square millimetres should be used for the wiring.

The dynamic RAM card

Experience has shown that the dynamic RAM card 'refuses' to operate with certain 6502 processors. Neither was the card very fond of the 6809 processor so far. For this reason we have made a few modifications to the dynamic RAM card which make it extremely reliable in conjunction with any 6502/6809 system. Figure 8 shows all the modifications required.

We wish you continued enjoyment with the DOS Junior Computer which is still the lowest-cost and favourite computer for home construction, with a disk operating system.

a dozen and one sounds...

an assorted box of sound effects

The circuit will be of great interest to experimentors musicians and recording enthusiasts alike. A single chip with a few surrounding components realises a circuit which makes a respectable job of reproducing sounds like, rain, explosions, cars crashing and so on. Ideal for mixing new film sound tracks.

No matter how unusual or irrelevant a sound may be, a use is always found for it and the number of people wanting to produce sound effects is simply amazing. To a certain extent noises of one kind or another are part of everyday life. In artificial environments such as recording studios, discos, concert halls and quiet front rooms the lack of birds chirping and explosions is noticeable. The only way to introduce well known and seemingly well loved (?) noises is to produce them synthetically. This is where the SN76477 IC comes into its own, because it contains all the ingredients of a BBC effects laboratory, producing a large number of refreshing sounds. This Texas IC is not new especially to Elektor readers. The main advantage of using a well proved component is that it is available at a relatively low price.

The IC

The article is aimed at the practical aspects and not the theory so we will stick to a brief survey of the most important features. The internal layout of the complex sound generator is given in figure 1. A closer look shows that there are three fundamental signals produced. These are obtained from: the super low frequency oscillator (SLF), the voltage controlled oscillator (VCO) and the noise generator.

The SLF provides two output signals: a square-wave processed by the mixer stage and a triangular wave form used to control the VCO by way of the external VCO/SLF select section.

The oscillator frequencies of each stage are determined by the various external RC networks. It is clear from just a rudimentary description that the SN 76477 is a very versatile IC.

The circuit

Because of the enormous capabilities of the IC, to create an endless repertoire is theoretically possible. But, for practical reasons a circuit able to produce a dozen or more different sounds is by far a better investment and a good basis for further experimentation.

Figure 2 shows the complete circuit in block diagram form. The potentiometers set the frequency of each stage. The VCO consists of an oscillator which is dependant on the input voltage. This control voltage can either be the SLF output signal or an externally applied one.

1
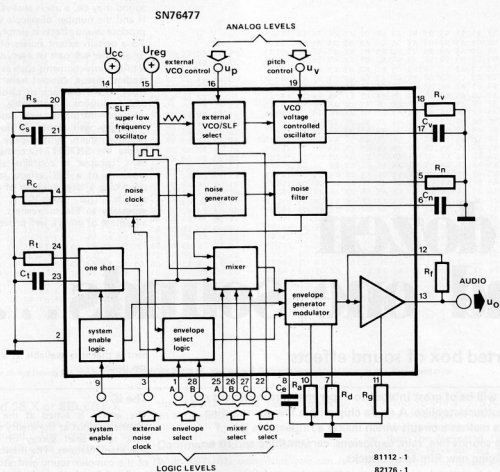
Figure 1. The block diagram of the internal components of the complex sound generator IC. It basically contains an SLF oscillator, a VCO and a random white noise generator.

2
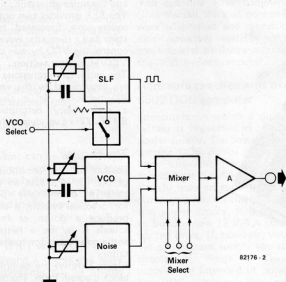
Figure 2. The complete circuit of the effects box in block diagram form.

The output signals from the three stages are fed to the mixer. Depending on the logic levels presented to the mixer select inputs, one, or a combination of the three is passed on.

Figure 3 illustrates the practical circuit design of the effects box. Apart from the complex sound generator IC nearly all the other components are just potentiometers and switches. Transistors T1 and T2 constitute a simple complementary pair AF amplifier with P4 as the volume control.

Because of the number of switches and potentiometers the easiest way to explain their function is to list them.

- P1 adjusts the clock frequency of the pseudo-random white noise generator.
- P3 sets the SLF oscillator frequency.
- S1 determines whether the VCO is controlled by the SLF signal (position 2) or not (position 1).
- S2 is used to switch from one SLF frequency range to another, (1 = high, 2 = low).
- S3, S4, S5 are connected to the select inputs of the mixer stage.
- P2 determines the VCO frequency.

3
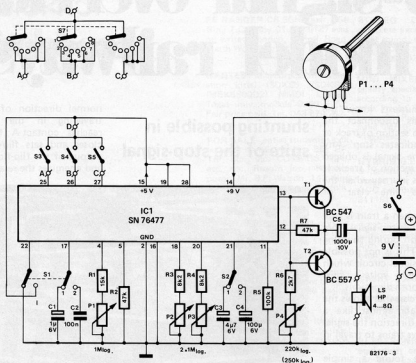
Figure 3. The circuit diagram of the effects box. S3, S4, S5 can be combined into one 8 way switch.

4　　　　　　　　　Table 1

closed switches	position of S7	mixer output
—	1	VCO
S4	2	SLF
S3	3	noise
S3, S4	4	VCO/noise
S5	5	SLF/noise
S4, S5	6	SLF/VCO/noise
S3, S5	7	SLF/VCO
S3, S4, S5	8	inhibit
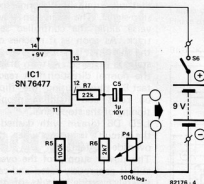
Figure 4. A suitable circuit providing a line feed to your hifi system.　　Table 1. The effect produced by each position of S7.

S3, S4, and S5 can be individual switches or combined into one 8 way 3 pole wafer (S7) as shown in figure 3. Table 1 itemises exactly what effect each position of S7 has.

Each new sound produced can be further modified by rotating any one or all of the potentiometers. Constructors wanting to experiment further can try new values for R3, R4 and R6.

Construction

With the accent on experimentation to produce a ready-made printed circuit board would be inappropriate, and anyway, as most of the components are switches and potentiometers it would be a waste of money. In fact vero board or something similar is ideal here.

Any 4 to 8 Ω speaker is suitable provided it can handle at least 100 mW. Substituting the amplification stage (T1, T2) with the circuit shown in figure 4 provides a line feed to any Hi Fi system or external power amplifier.

A single 9 V battery is sufficient. This is because the IC contains its own internal voltage regulator (not shown in figure 1) which derives a stable 5 V from the original input voltage (pin 14 9 V in, pin 15 5 V out)). The current consumption will depend on the output volume but it should not exceed 50 mA.

◀

stop-signal override for model railways

shunting possible in spite of the stop-signal

Model railway enthusiasts know the problem: stop-signals disconnect the supply voltage from a section of track as soon as the signal indicates 'stop'. Any train approaching the signal is obliged to stop on the dead section of track. It can only continue its journey when the stop-signal indicates 'line clear' or 'reduce speed'.

The problem arises when a train is supposed to approach the stop-signal from the opposite direction during shunting or at rural stations. This is not possible with the usual stop-signal circuit which disconnects the supply voltage, thus preventing traffic in both directions.

What we need is a circuit that allows the stop-signal to operate almost like a diode: in the normal direction the signal stops trains but allows trains to travel in the reverse direction.

As usual, we have found a simple solution.

In addition to the stop-signal we need two rail contacts at the two ends of the controlled section (see figure 1). These are contact A at the end and contact B at the beginning, when viewed in the

normal direction of travel. The train travelling in the reverse direction reaches contact A first. The contact closes and sets flip-flop IC1. The Q-output of the flip-flop goes to logic '1' and energizes the relay via T1. The relay
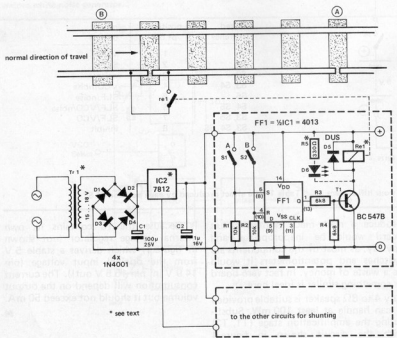
contact closes and bridges the circuit that was originally disconnected by the stop-signal. The train can travel in reverse along the controlled section of track. As soon as it reaches contact B the flip-flop is reset and the original state is restored. A train travelling in the normal direction first reaches contact B, thus causing the flip-flop to be reset and enabling proper functioning of the stop-signal.

LED D6 (drawn with dashed lines in the circuit) lights up when the signal override is effective.

The power supply of the override circuit is generously rated and can power several override circuits of this type. The current drawn by one of these circuits depends on the relay used. Transistor T1 can supply a maximum relay coil current of 100 mA.

Instead of using a separate transformer for the power supply, the AC voltage can also be obtained from the 'lighting output' of the model railway transformer.

If a 12 V relay is utilized the AC voltage required is 15 . . . 18 V and a 7812 voltage regulator is needed for IC2. With a 5 V relay a type 7805 regulator must be used for IC2, in which case the transformer secondary voltage should be approximately 8 . . . 12 V. With a relay voltage of 5 V, the value of R5 should be 120 Ω.

1

normal direction of travel

FF1 = ½IC1 = 4013

IC2 7812

FF1

BC 547B

4x 1N4001

* see text

to the other circuits for shunting

elektor switchboard

JUNIOR computer + interface + Elekterminal + ASCII-keyboard + power supply uncased £ 15. Write 1. Japan St., Cheetham, Manchester.

WANTED 5¼'' disk drives (Teac or Olivetti but Shugart considered). Tel: Great Yarmouth 62102 after five.

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ALL WANTED complete years of "Elektors", computer and radio test equipment, unbuilt kits, H.F. triband beam, 041-884.4988.

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elektor switchboard December

market

Sealed switch

EECO have introduced the environmentally sealed MINI-DIP switch. This model features a flexible, clear cover and an epoxy bottom seal. The switch can be actuated directly through the flexible cover. This configuration offers a maximum protection during the wave soldering and cleaning processes, as well as when used in hostile environmental conditions. The seal will maintain its integrity
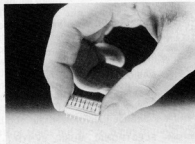

when subjected to a range of temperature and solvents.

The 2400 series MINI-DIP offers standard gold-on-gold true wiping action contacts and strong .508 mm x .355 mm terminals to virtually eliminate insertion and alignment problems. Standard 2.54 mm x 7.62 mm centres make MINI-DIP compatible with other major brands.

EECO Sales,
Telephone: 0954.8025

(2477 M)

Small instrument enclosures

The K-series of instrument housings is now available from Alusett UK Limited, based in Winchester, Hampshire. These enclosures comprise front and rear satin anodised panels that attach to a tubular blue powder-dipped aluminium cover using brass fixing bushes.
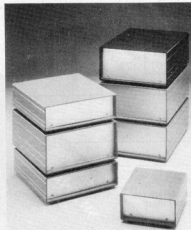
Six sizes, from 90 x 42 x 100 mm to 138 x 66 x 200 mm, are available and separate chassis are offered which can be secured to the front and rear panels using 3.5 mm screws. Special sizes, configurations and colours, can be supplied by Alusett to suit non-standard requirements.

Alusett UK Ltd.,
Whiteshute Lane,
Winchester
Telephone: 0962.68673

(2509 M)

Alphanumeric keypads

A range of cost-effective keypads, formed from Shin-etsu conductive silicon rubber is now available from N.S.F.

Advantages of this range include . . .

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- reduced assembly costs
- one-piece construction
- elimination of spring and plunger assembly
- low chatter and bounce
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- non-discolouration of pads

Most conventional keyboards for computer data entry incorporate metal contacts and mechanical actuation. Dirt, dust and other contaminants will, of course, render this type of construction liable to failure should they get between the contacts. Also, economically, such keyboards tend to be costly due to the use of gold plated contacts and to a more labour intensive manufacturing and assembly system.

ALPHANUMERIC KEYPADS
FORMED FROM CONDUCTIVE
SILICON RUBBER

In comparison, the new keyboards are formed with conductive rubber instead of metal for the key contacts and silicon rubber domed membranes instead of mechanical switches.

N.S.F. Limited,
Switches and controls,
Keighley,
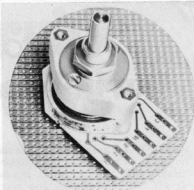*West Yorkshire BD21 5EF*
Telephone: 0535.61144

(2508 M)

BCD switches

The model CBS switches from N.S.F. are available in both binary and binary coded complement outputs. They are provided with various terminations including pcb and wire-wrap. The moulded indexing mechanism is fully enclosed giving effective protection for the rotor connections to the printed circuit tracks. Four indexing configurations are available:

12 positions at 30°
16 positions at 22.5°
24 positions at 15°
32 positions at 11.25°

Stops can be fitted as specified or made adjustable for customer adjustment.
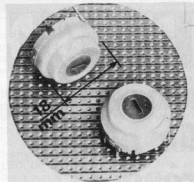
The model CBS switch has a switching ca-

pacity of 3 VA with a resistive load, switches a maximum current of 100 mA, a voltage of 60 V rms and has an insulation resistance of not less than 50,000 megohms.

N.S.F. Limited,
Keighley,
Yorkshire BD21 5EF
Telephone: 0535.61144

Subminiature binary coded wafer switch

The CLSA from NSF is a small, moulded, binary coded, single wafer, rotary switch for pcb mounting. The compact and low profile of this switch, manufactured to the EBE system, accommodates both the index mechanism and the switching contacts in a single moulding, 18.6 mm dia. and only 10 mm deep, and also has the position numbers moulded into the face.

Model CLSA has a switching capacity of 3 VA max. with a resistive load, carries 1 A and has an insulation resistance of 10,000 megohms. Contacts incorporate a gold flashed finish.

N.S.F. Limited,
Keighly,
Yorkshire,
BD1, 5EF.
Telephone: 0535.61144

(2480 M)

market

market

Voice response unit

The VR8 Voice Response Unit provides clear, human speech output from existing computers over the dialled telephone network. The VR8 automatically accepts incoming calls from telephones with multi-frequency tones or standard telephones with pocket sized 'Minitone' keypad attached, and passes the data to a computer in the normal manner. The speech facility is activated by commands from a computer and the Unit's own microcomputer then delivers speech down the telephone line.

Although the system is expected to operate mainly over the telephone, the unit may also be used to provide speech in conjunction with

or as an alternative to computer output, normally associated with Video displays, where speech may be more convenient than the printed word.

This device provides an inexpensive, simple to use method of communicating with a computer for the non-technical user. The Voice Response Unit can easily be added to virtually any business computer and is compatible with View Data Systems. Speech which may be recorded by the user is held in ROM. Other manufacturer's speech systems, such as National Semiconductors 'Digitalker' with large vocabulary, are standard options on the VR8.

For users who require a lengthy or constantly changing vocabulary there is the highly sophisticated, multi track, cassette tape option, the VR5. This unit enables the user to change or add recordings by using a conventional plug in microphone. The VR5 has the unique ability to search for speech during data entry and of having more than one recording at a given location which, together with its high search speed, virtually eliminates response delays. Applications responding to the same computer program but in more than one language are also within the capabilities of

this unit. The VR5 and VR7 may be combined providing both tape and solid state memory in a single unit.

The Unit is available with a standard RS 232C interface and both IBM and ICL interactive protocols are also catered for.

Medway Data Limited,
Victoria House,
Grover Street,
*Tunbridge Wells,*
Kent TN1 2QB
Telephone: 0892.44462

(2502 M)
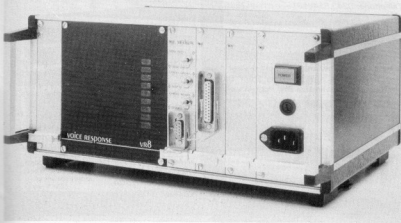
Heating controller

This unit is designed to control the temperatures inside buildings enabling central heating systems (oil, gas, electricity) to work more economically and therefore save direct energy.

It provides a 4 program daily cycle controlling the temperature at any given period. These programs are totally independent and therefore it is possible to select day and night temperatures separately as desired. The display functions as a clock as well as a thermometer. The different programs may be called, verified and changed individually.
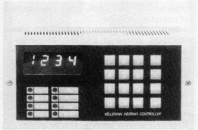
This unit replaces conventional mechanical thermostats without additional wiring and it has an additional advantage; the hysteresis may be programmed at choice. It is also possible to control the unit manually without disturbing any of the pre-selected-programs. The main savings are obtained by a more accurate measuring of time and temperature and precise ON and OFF switching, eliminating mechanical tolerances. The unit is built around a specially designed 'single chip microcomputer' and based on the most advanced technologies.

It is available in kit-form and also as a built and tested unit.

Velleman (U.K.) Limited,
P.O. Box 30,
St. Leonards-on-Sea,
East Sussex TN37 7NL
Telephone: 0424.753246

(2507 M)

market
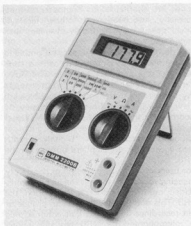
market

High-specification, low-cost test equipment

Sifam Ltd of Torquay is now marketing a range of test instruments and accessories.

Available now with one-year guarantee, prices exclusive of VAT) are: **Handheld 3½ digit (1999) multimeter, model DMM2200B**, priced at £ 43.43, offers 21 ranges in five modes: DC & AC voltage and current, and resistance. Said to have a basic accuracy of 0.3 per cent (DCV), the instrument will operate continuously for 1000 hours from a standard 9 V radio-type battery, and has overload protection, autozero and autopolarity facilities as well as over-range and low-polarity indications.

Robustly constructed, two rotary switches provide clear and simple colour-coded selection of measurement mode and range, and the read-out is by 12 mm high LCD digits. It measures 165 x 110 x 43 mm, weighs 360 grammes with battery, and is supplied complete with test leads, spare fuse, battery and operators' manual.

3½ digit (1999) bench multimeter, model DMM2500, priced at £ 66.04: 24 ranges in the same five DC/AC measurement modes, with the same order of accuracy and operational features, but with push-button function/range switching and 2000 hours battery life and circuit-breaker overload protection. It has a built-in bench stand/handle and measures 165 x 120 x 57 mm, weighs 383 grammes with battery. It is supplied with test leads, battery and manual.

Digital logic probe, model DLP50, compatible with DTL, TTL and CMOS standards, this too, says Sifam, offers exceptional value for money at £ 39.09. It has an input frequency range of DC to 50 MHz, a minimum detect-

able input pulse width of 10 nanosecs, high input impedance of 10 megohms, power range of 4.5 to 30 V DC with input protection (including an audible warning) up to ± 120 V DC or AC. Three-colour LEDs signal: high (red), low (green), open-circuit/bad level
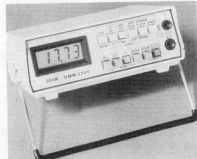
(yellow) and pulse/memory (red). The audible alarm sounds if an input signal exceeds the operating voltage of the circuit under test, or when a voltage in excess of 30 V DC is applied to the probe input, if the power lead is connected in reverse or with AC line. The probe is fitted with a 800 mm long power lead, and has a consumption of 50 mA maximum at 5 V DC. Dimensions of the probe itself are 195 x 26 x 16 mm and it weighs 70 grammes. Supplied in a moulded carrying case, it comes complete with ground and IC clip leads and operating manual.

REA publicity,
6 St. James Square,
Cheltenham,
Gloucestershire GL50 3PR
Telephone: 0242.514418

(2505 M)

LCD modules

A new range of dot matrix liquid crystal display modules, is now available from Datac Limited. Compact in size and light in weight,
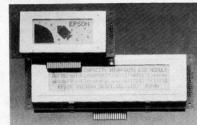
Epson EA series LCD modules are available with character formats ranging from 16 x 1 line to 80 x 4 lines and a dot format of 84 columns x 32 rows.

Operating on a 5 V DC power supply, with a consumption of 0.6 to 3 ma, EA and EG LCDs have a high contrast display for easy readability. Backlighting can be provided. EA and EG series modules have a built-in Data RAM (80 Bytes) and character generator (160 ch based on ASCII code). The modules will operate at any temperature from 0 to 50°C and have a response time (turn on/turn off) of 150 ms. The design life is 50,000 hours.

Datac Limited,
Tudor Road,
Altrincham,
Cheshire WA14 5TN.
Telephone: 061.941.2361/2.

(2521 M)

20 A relay

Introduced as the Magnacraft Class 389, this new power relay features extremely high contact ratings for its size: it can be supplied in open style, which measures 2.1 in. long x 1.45 in. wide x 1.28 in. high; or with a clear plastic flange-mount cover, measuring overall 2.9 in. long x 1.5 in. wide x 1.4 in. high. Its base incorporates quick-connect/solder terminals.
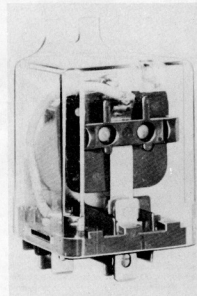
The most important feature of the Class 389 is its power switching capability. The relay is available in single, double or triple throw contact configurations rated at 20A per pole. A further version, designated 389 DZ, features double break and double make contacts rated at 30A.

Contact horsepower ratings range from ½ hp to 1½ hp, according to contact configuration and the voltage of the motor to be controlled. Coil voltages range from 6 V a.c. to 277 V a.c. or 6 V d.c. to 220 V d.c.

Diamond H Controls Ltd.,
Vulcan Road North,
Norwich NR6 6AH.
Telephone: 0603.45291/9.

(2514 M)
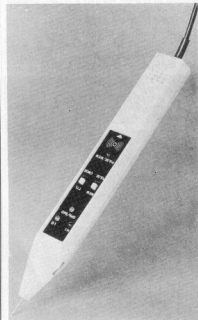
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301 circuits

The book follows the theme, and is a continuation of our popular and very successful 300 circuits publication. It is composed of 301 assorted circuits ranging from the simple to the more complex designs described and explained in straightforward language. An ideal basis for constructional projects and a comprehensive source of ideas for anyone interested in electronics. In a nutshell something to please everybody.